IMAGING & MACHINE VISION EUROPE

For suppliers, integrators and OEMs using machine vision

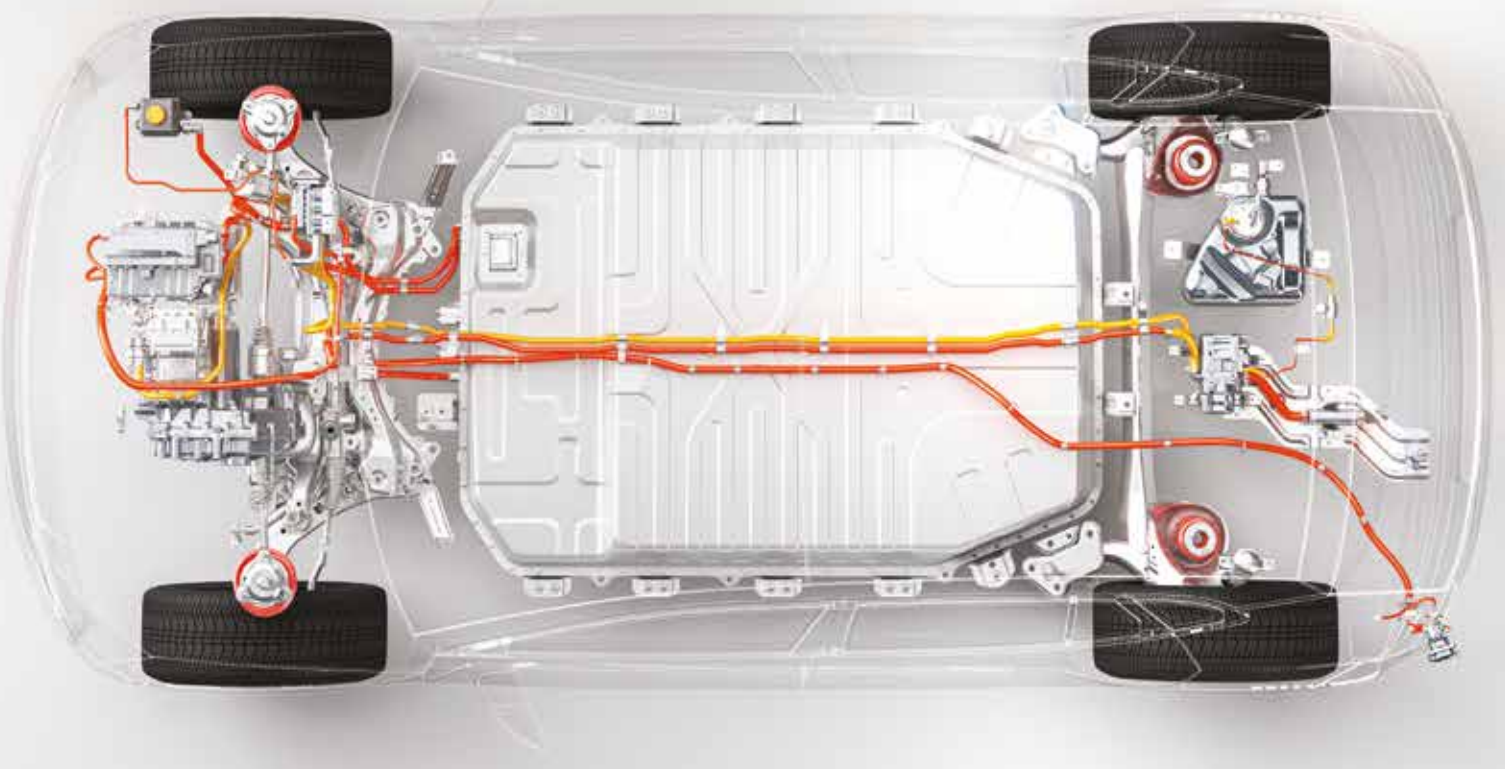
February/March 2022
Issue 109

ST's quantum dot sensor set for volume SWIR

Vision finds ways to improve fish farms

Work begins on camera API standard

Summing up the latest industrial image sensors



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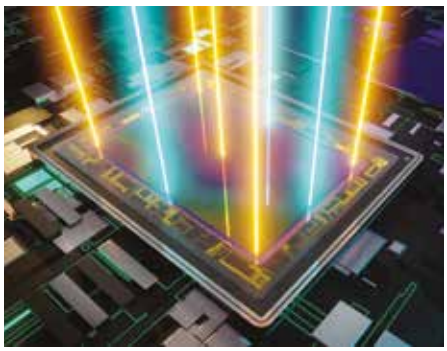
Leader
Greg Blackman

A short wave at the future



Late last year, STMicroelectronics announced details of its quantum dot shortwave infrared image sensor, joining pioneers in this space such as SWIR Vision Systems and Emberion. STMicroelectronics is making its sensors on 300mm wafers, which opens up the potential for volume production, and as the technology is scaled up the cost goes down. It feels like this could be the beginning of a new era in shortwave infrared imaging, because quantum dot detectors make SWIR sensing much more accessible than was possible with the inherently more expensive InGaAs. InGaAs still has higher quantum efficiency at longer wavelengths, but the value proposition will shift towards using thin film quantum dot detectors as the technology improves. Sony's SenSWIR devices are a marked improvement on the InGaAs side, and there are now a number of machine vision cameras based on these detectors.

In this issue, we report on STMicroelectronics' announcement, along with Emberion's plans as it raises investment in a new round of funding (page 12). There's also analysis on page 15 on the SWIR imaging landscape from Imec's Paweł Malinowski, who is working on Imec's own quantum dot SWIR sensor offerings.

This issue also covers electric vehicle battery production (page 16), and the use of computer vision in fish farming and aquaculture (page 20), both areas – at least, in agriculture in general – where shortwave infrared imaging could play more of a role in the future.

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www.linkedin.com/showcase/imaging-and-machine-vision-europe

Editorial and administrative team
Editor Greg Blackman
Tel: +44 (0)1223 221042
greg.blackman@europascience.com
Technical writer Matthew Dale
Tel: +44 (0)1223 221047
matthew.dale@europascience.com
Senior designer Zöe Andrews
Tel: +44 (0)1223 221035
zoe.andrews@europascience.com
Partnership & Events Executive Charlie Mitchell
Tel: +44 (0)1223 221033
charlie.mitchell@europascience.com

Advertising team
Advertising sales manager Eleanor Waters
Tel: +44 (0)1223 221031
eleanor.waters@europascience.com
Art/production manager David Houghton
Tel: +44 (0)1223 221034
david.houghton@europascience.com

Corporate team
Managing director Warren Clark
warren.clark@europascience.com

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Tel: +44 (0)1223 221030.
Fax: +44 (0)1223 213385.

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EUROPA SCIENCE

News

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David Dechow joins Landing AI

David Dechow, formerly of Integro Technologies, has joined AI software firm, Landing AI, as VP of outreach and vision technology.

Landing AI was founded by AI veteran, Andrew Ng, to bring AI technologies to manufacturing and industrial inspection. The company said that Dechow's 35 years of experience in machine vision will 'further enhance Landing AI's mission of bringing the benefits of deep learning-based inspection to all industries, including electronics, automotive and medical devices.'

Before joining Landing AI, Dechow was principal vision systems architect at vision integrator, Integro Technologies, which is now owned by the Kaman Distribution Group. He is a member of the A3 Vision and Imaging Technical Advisory Board in the US, and the A3 Vision and Imaging Education Committee.

'We're thrilled to have David join Landing AI and bring his hands-on expertise to helping manufacturers use cutting-edge deep learning,' said Andrew Ng, founder and CEO of Landing AI. 'The next era of AI is one in which companies in all industries access the benefits of AI. David's deep knowledge of machine vision and automation will help us get there.'

The evolution of AI and deep learning is changing the software part of machine vision and, when applied correctly, can make machine vision tools more efficient and productive.

With Landing AI's data-centric approach, the application of deep learning no longer depends on big data but on the data that entities actually have, in many cases even when the amount of available data is limited.

'Adoption of deep learning for machine vision applications has been somewhat slow because of practical problems, including the challenges of online imaging and, most importantly, the potentially small datasets deep learning technology could not handle,' said Dechow. 'But Landing AI's technology

makes cutting-edge deep learning work for automated inspection, and I look forward to helping bring these benefits to all manufacturers.'

Landing AI developed LandingLens, an enterprise MLOps platform. It helps manufacturers apply AI and deep learning to solve visual inspection problems, find product defects more reliably, and generate business value.

Basler acquires Korean sales partners and joins 5G Alliance

Basler has bought its sales partners in Korea to expand its business in Asia. It has also joined the 5G Alliance for Connected Industries and Automation, the first machine vision firm to do so.

The purchase of Datvision and Iovis follows Basler's acquisition of vision distributor MVLZ in China in 2018, to give Basler a direct route to market in these regions. Basler plans to merge the two Korean companies to create a subsidiary of around 50 employees.

Asia accounted for 55 per cent of Basler's revenue over the first three quarters of 2021.

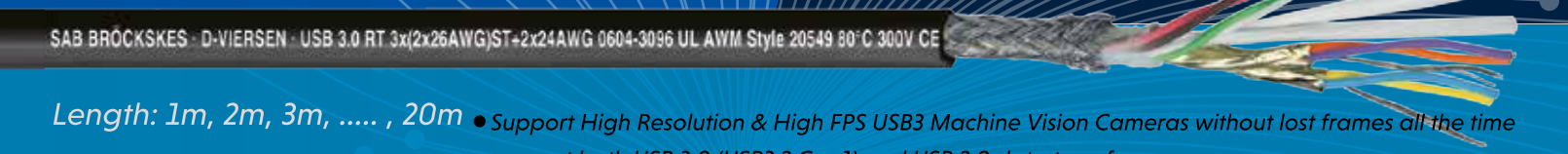
In joining the 5G Alliance, Basler signals its belief in 5G wireless communication as an important building block in Industry 4.0 and industrial IoT. The alliance aims to bring together various industries from the information technology and operational technology sectors to develop standards for 5G.

Basler

From left: Chong Yoon Foo (Basler), Hyunki Cho (Datvision), Kim Jonghwan (Iovis), Dr Dietmar Ley (Basler)

LONG DISTANCE CONNECTION

USB3.2 Gen1 MACHINE VISION CABLES ROBOTIC



Length: 1m, 2m, 3m, ... , 20m

O.D.: 8.0~8.8mm

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- *USB 3.0 (USB3.2 Gen1) bus-powered, no external power supply needed*

SAB® USB 3.0 RT raw cable
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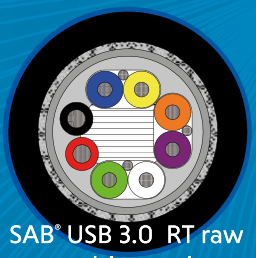
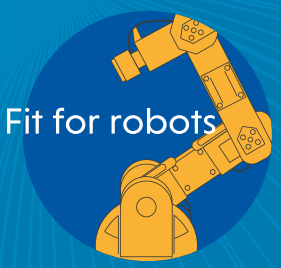
fixed laying: 5 x d
flexible application: 10 x d
continuously flexible: 15 x d
torsion angle: up to +/- 360°/m



SAB® USB 3.0 RT raw cable used



USB3.2 GEN1 TYPE-C CABLES

CBL-RTPD3SABCS - 1m ~ 5m CBL-RTD3SABCS - 5m, 6m, ... , 20m

Standard A Plug with locking screws

Angle Type-C

Left & Right
CBL-RT(P)D3SABCS - xmLRA

Up & Down
CBL-RT(P)D3SABCS - xmUDA

USB3.2 GEN1 Micro-B CABLES

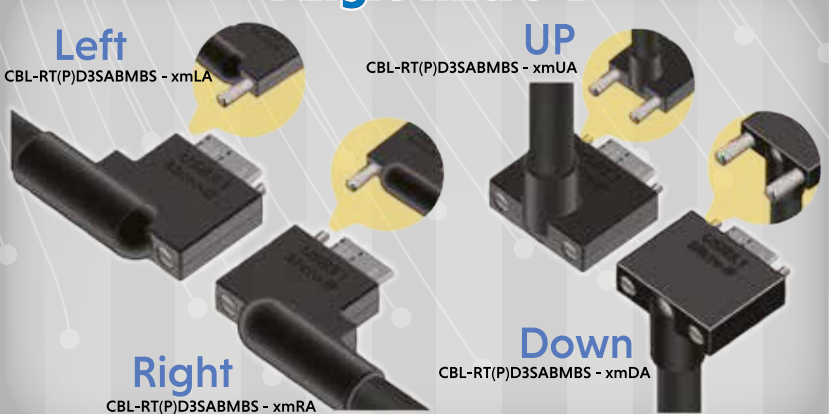
CBL-RTPD3SABMBS - 1m ~ 5m CBL-RTD3SABMBS - 5m, 6m, ... , 20m

Standard A Plug with locking screws

Angle Micro-B

Left
CBL-RT(P)D3SABMBS - xmLA

UP
CBL-RT(P)D3SABMBS - xmUA



Right
CBL-RT(P)D3SABMBS - xmRA

Down
CBL-RT(P)D3SABMBS - xmDA

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SiLC targets robot guidance with chip-scale lidar

Silicon photonics firm, SiLC Technologies, has launched a lidar vision sensor aimed at robotics and machine vision.

SiLC announced a collaboration with Hokuyo Automatic to develop cost-effective 4D lidar solutions for the next generation of industrial and robot applications.

The Eyeonic vision sensor is a chip-scale lidar, in that it integrates all the components – including an ultra-low linewidth laser, a semiconductor optical amplifier and germanium detectors – into a single silicon chip.

SiLC's silicon photonics platform is based on semiconductor fabrication processes, offering a low-cost, compact and low-power solution.

SiLC uses frequency modulated continuous wave (FMCW) technology at 1,550nm wavelength, rather than operating at 905nm. The company says the vision sensor gives millimetre precision at long distances.

Eyeonic also offers dual-polarisation intensity information, and is immune to multi-user and environmental interference.

Hitoshi Ozaki, president at Hokuyo, stated: '4D lidar will provide longer range, higher precision, instantaneous velocity and interference-free operation. SiLC is the first company to integrate all of the laser, detectors and optical processing technology needed to create compact, viable solutions in the market. Our collaboration with SiLC enables us to jointly architect an FMCW lidar solution that extends Hokuyo's leadership and customer solutions.'

'Industries are eagerly embracing robotic automation strategies,' Mehdi Asghari, CEO of SiLC, added. 'For machines to reach their full potential, a highly tuned vision element is needed – and that is where we come in. Collaborating with Hokuyo allows us to bring our FMCW technology to market.'

SiLC Technologies

Eyeonic vision chip

Recycling top of UKIVA conference agenda

UKIVA
UK Industrial Vision Association

By Neil Sandhu, UKIVA chairman

The last few months have been particularly busy for UKIVA. Preparations for the 2022 Machine Vision Conference and Exhibition (MVC 2022) have intensified and the latest issue of our biannual *Vision in Action* publication has been circulated.

MVC 2022 (www.machinevisionconference.co.uk) returns to the Marshall Arena, Milton Keynes, on 28 April as a live event for the first time in two years – registration is now open at: rfg.circdata.com/publish/MVC22. The first keynote from Seb Millar, who is the machine learning engineering manager at Recycleye, is sure to be popular. This fascinating keynote will address ways in which advanced machine learning, computer vision and robotics can be applied to improve waste recycling efficiencies at materials recycling or recovery facilities.

Economics are a crucial element of the recycling effort. Recycleye CEO Victor Dewulf commented: 'Waste is not recycled when the cost of recycling exceeds the value of the sorted material. By lowering the cost of recycling with artificial intelligence and robotics, this threshold can be broken and removal chains can be fully integrated back into supply chains.'

Current UK regulation requires facilities to sample just 0.05 per cent of waste, but the combination of AI, smart analytics and low-cost cameras enables 100 per cent analysis. The use of vision inspection ensures no physical alterations are required to packaging or production processes, and robot picking systems enable automated sorting of waste.

Recycleye has also partnered with academics at leading universities to create WasteNet, the world's largest open-source database for waste. This holds more than three million training images created by deep learning and computer vision. WasteNet can be used to identify waste items at a brand and weight level. By applying machine learning, the granularity of waste sorting can be increased by, for example, differentiating food and non-food-grade plastics (which was previously not possible), and in the process the resale value of bales can be significantly increased.

Readers in the UK will have received a copy of UKIVA's latest *Vision in Action* publication, containing product news, real-world application stories, and a feature on out-of-the-box vision solutions. It is really important for industry at large to understand there are many ready-made vision solutions available, and to dispel the myth that adopting the use of vision can only be handled by vision specialists. One enduring feature of machine vision is the multitude of building blocks that make it a truly enabling technology for a myriad of applications across many industries. Anyone who hasn't received a copy of *Vision in Action* can access it online: www.ppma.co.uk/ukiva/publications/vision-in-action.html.

Researchers achieve 3D imaging through single optical fibre

A team of scientists, led by the University of Glasgow's Optics Group, has built a 3D imager able to capture video at 5Hz through a single optical fibre.

The prototype system delivers images through a 40cm-long optical fibre, each frame containing up to approximately 4,000 independently resolvable features, with a depth resolution of around 5mm.

The work, which has been published in the journal *Science*, has applications in industrial inspection, environmental monitoring and medical imaging.

Normally, when light shines through an optical fibre, crosstalk between modes scrambles the light to make the image unrecognisable. To resolve this, the team used advanced beam shaping techniques to pattern the input laser light to the fibre to create a single spot at the output. That spot of light then scans over the scene and the system measures the intensity of the backscattered light into another fibre – giving the brightness of each pixel in the image.

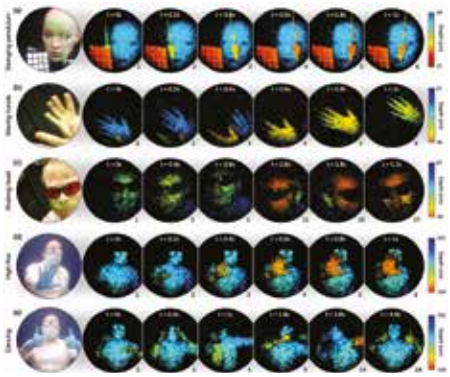
By using a pulsed laser, the device also measures the time of flight of the light and hence the range of every pixel in the image. These 3D images can be recorded at distances from a few tens of millimetres, to several metres away from the fibre end, with millimetre distance resolution and frame rates high enough to perceive motion at close to video quality.

'We are developing a new technique for imaging through a single fibre the width of a human hair'

Professor Miles Padgett, Royal Society Research Professor at the University of Glasgow and principal investigator for Quantic, the UK Hub for Quantum Enhanced Imaging, said: 'In applications like endoscopy and boroscopy, imaging is traditionally achieved by using a bundle of optical fibres, one fibre for every pixel in the image, resulting in devices the thickness of a finger.

'As an alternative, we are developing a new technique for imaging through a single fibre the width of a human hair. Our ambition is to create a new generation of single-fibre imaging devices that can produce 3D images of remote scenes.'

Currently, the multimode fibre must remain in a fixed position after calibration.



University of Glasgow / Quantic

Future research will look at reducing the calibration time and managing the dynamic nature of bending fibres. The team aims to work with industry to develop this research into functional technology within the next 10 years.

Grain of salt

Sticking with micro-sized cameras, researchers at Princeton University and the University of Washington have developed a camera the size of a coarse grain of salt.

The device, half a millimetre wide, uses an optical system called a metasurface. The surface is studded with 1.6 million cylindrical posts, each with a unique geometry and functioning like an optical antenna.

Varying the design of each post shapes the optical wavefront, and understanding how the posts interact with light, using machine learning, produces an image.

The metasurface camera can produce full-colour images on par with a conventional compound camera lens 500,000 times larger in volume, the researchers reported in a paper in *Nature Communications*.

Like the fibre optic imager, the metasurface camera could be used for minimally invasive endoscopy, as well as for sensors for robots.

The researchers also say that arrays of thousands of such cameras could be used for full-scene sensing, turning surfaces into cameras.

The imaging performance is achieved through a combination of the design of the metasurface features, together with the post-detection processing.

The group is now working to add more computational abilities to the camera, such as object detection and sensing modalities relevant for medicine and robotics.

In brief

Atlas Copco, which owns Isra Vision, has acquiring **Soft2tec**, a provider of camera-based tracking systems for operator guidance in the automotive, aerospace and general industries. Soft2tec, based in Rüsselsheim am Main, Germany, has 38 employees and revenue in 2020 of €1.87m.

Photoneo has raised $21m to expand its automation solutions for warehouses. The 3D imaging firm has announced a new business unit, called Brightpick, which provides automation systems for logistics based on autonomous mobile robots and robot picking. The investment round was led by IPM Group.

Stemmer Imaging has received a €12m order from a customer in the sports and entertainment segment.

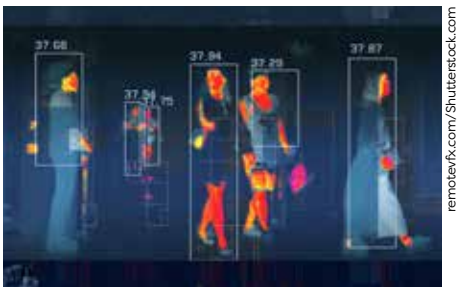
Owl's 3D thermal imaging tech raises $15m

Owl Autonomous Imaging has attracted $15m in investment to further its monocular 3D thermal imaging and ranging solutions for automotive safety.

Owl is a Silicon Valley thermal imaging start-up with offices in Rochester, NY. Its thermal ranging technology was initially designed to track missiles, but has been adapted for driver assistance systems to detect pedestrians.

The company's technology is based on HD thermal imaging, with algorithms exploiting angular, temporal and intensity data to produce dense point clouds and refined object classification.

The company recently completed field trials in conjunction with VSI Labs in Las Vegas during CES 2022.



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The funding was led by State Farm Ventures, with participation from Excell Partners, Luminate NY Accelerator – Owl was part of Luminate's accelerator programme – Empire State Development, MHNW Consortium, Dr Sanjay Jha (former CEO of both GlobalFoundries and Motorola Mobility), as well as others.

Demand high, but supply chain woes remain

VDMA Machine Vision

By Anne Wendel, VDMA Machine Vision

Last year concluded with a new VDMA forecast: the German robotics and automation industry expects its turnover to grow by 10 per cent in 2022. The sector, with its three sub-sectors – robotics, machine vision and integrated assembly solutions – currently has a high order backlog and sees a positive investment climate in key customer industries. The robotics and automation industry is well on track to reach its 2021 growth forecast of 11 per cent and expects another 10 per cent growth in sales for 2022.

The prerequisite for this is that the current disruptions in supply chains do not intensify significantly. For the European machine vision industry, the current official forecast is still 7 per cent growth in sales for 2021 and 2022. However, the current figures from the VDMA monthly statistics indicate that these positive figures will be exceeded, if the shortage of electronic components does not hamper production too much.

However, according to the latest surveys and discussion among VDMA Machine Vision members, there is no improvement in sight. There is virtually no company not suffering from the chip shortage, including component manufacturers, as well as system integrators. The 28th edition of the annual VDMA Machine Vision market survey, with direct feedback from companies all over Europe, will provide a sound overview of the industry, as well as an outlook and a market forecast.

Trade shows are back!

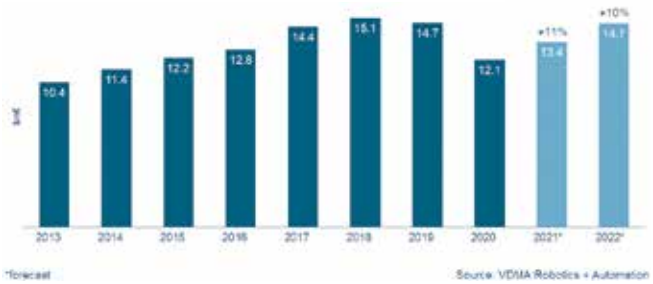
The summer to autumn months this year are going to be a busy time. VDMA Machine Vision will support its membership with a wide range of activities at three trade shows: Automatica, Vision China Shanghai and Vision in Stuttgart.

At Automatica 2022 – 21 to 24 June in Munich – the trade fair organiser, Messe München, in cooperation with VDMA, offers companies the opportunity to exhibit at low cost within the Automatica machine vision pavilion. The joint booth concept provides a shared lounge, co-use of the infrastructure (lounge, barista) from the nearby VDMA Robotics and Automation association's booth, as well as a presentation programme about vision technology. Many of the important players from robotics and automation have already registered for the show.

At Vision China Shanghai – just postponed to 13 to 15 July – the VDMA Shanghai representative office, in cooperation with VDMA Machine Vision, is organising a VDMA joint booth, which aims to raise the visibility of the exhibiting members in the Chinese market.

Needless to say, our focus is on the Vision trade fair – 4 to 6 October – where VDMA Machine Vision will be present as a conceptual partner. Together with Messe Stuttgart, we will organise the Industrial Vision Days, a three-day presentation forum with around 60 lectures covering a wide range of technical and application-related machine vision topics. VDMA Machine Vision will also be involved in the Vision start-up area, together with the VDMA Startup-Machine.

German Robotics and Automation global turnover (in billions of Euro) 2013 - 2022*



Milk vodka distiller's labelling 100% proof with vision

Dairy Distillery and Pleora

A distillery that turns dairy by-products into vodka has installed machine vision to add decision support to its labelling process.

Dairy Distillery, based in Almonte, Ontario, set up a station using Pleora's AI-based Visual Inspection System to help ensure brand consistency for operators labelling bottles manually.

The distillery trained a camera to identify key brand elements on the bottle, with a real-time, on-screen image overlay guiding operators as they manually place an associated emblem.

Pleora's camera-based Visual Inspection System integrates pre-packaged AI plug-ins that are trained according to a customer's requirements to highlight product differences and deviations.

The system helped the distillery reduce costs and avoid production downtime, as labelling errors can be avoided or detected earlier in the process.

Dairy Distillery has pioneered a process that uses milk permeate – a by-product from making food such as butter, ice cream and yogurt – to distill vodka. The business now ships more than 100,000 bottles of its Vodkow vodka and cream liquors globally.

The distillery's Vodkow bottle has a label placed by a machine and an emblem that is hand-placed by a human operator. The operator needs to align the emblem with brand elements on the main label.

'The Visual Inspection System integrates pre-packaged AI plug-ins that are trained according to a customer's requirements'

'We're a world-class product, and our packaging needs to look perfect every time,' said Neal McCarten, co-founder and director of marketing for Dairy Distillery. 'When you say you're making vodka from milk, it can be a leap of faith for a consumer until they taste the product. Our packaging, fashioned after a traditional milk bottle and eye-catching labelling... helps a consumer connect with the story behind the product. Consumers often judge what's inside a bottle based on its appearance.'

In addition to helping with brand consistency, Pleora's Visual Inspection System is used as a training tool to teach new employees brand quality standards.

Dairy Distillery is now investigating ways to use Pleora's system for quality control checks for in-production and finished goods.

Work to begin on camera API standard

A working group has been formed to develop an open API standard for controlling embedded cameras – and cameras in general – across mobile, industrial, XR, automotive and scientific markets.

Last year, more than 70 companies participated in a group hosted by Khronos and the European Machine Vision Association to develop a Scope of Work document, guiding the direction of the application programming interface (API) design.

Design work is expected to start in February 2022; those wanting to participate are invited to join. The Khronos group is an open consortium of companies creating interoperability standards. Participation in the initiative follows its multi-company governance process.

The aim is to improve interoperability between devices. The API standard should reduce application development time as well as integration and maintenance costs. It should make software code more portable, providing an opportunity for code reuse.

Neil Trevett, Khronos president, said that the work done last year in the exploratory group formed a consensus on the need, terminology, scope, requirements and design methodology for a new open standard camera system API.

He added: 'We warmly invite any interested companies, vendors and developers to bring their voice and their expertise to the design phase of this important work.'

The group will be of particular interest to sensor or camera manufacturers, silicon vendors and software developers working on vision and sensor processing.

The camera API will be designed to provide applications, libraries and frameworks with low-level, explicit control over camera run-times. It will have a low level of abstraction that still provides

'The aim is to improve interoperability between devices'

portability across a range of camera systems.

Companies involved in establishing the working group include: Adimec, Almalence, Analog Devices, Basler, Baumer Optronic, Cadence Design Systems, Collabora, Digica, Digital Air Technologies, Euresys, the European Machine Vision Association, Flir Integrated Imaging Solutions, Google, Groget, Holochip, Ideas on Board, LunarG, Matrix Vision, MM Solutions, MVTec Software, Nvidia, Perey Research and Consulting, Phil-Vision, Pleora Technologies, Raspberry Pi, Stemmer Imaging, Texas Instruments, VeriSilicon and Vision Components.

Christine Perey, Interoperability and Standards programme leader for the Augmented Reality for Enterprise Alliance, said: 'The lack of API standards for advanced use of embedded cameras and sensors is an impediment to industry growth, collaboration and innovation. Enterprise AR customers and systems integrators/value-added providers will benefit from greater clarity, open interfaces between modular systems and innovation in the component provider ecosystem.'

Laurent Pinchart, CEO of Ideas on Board and lead architect of the Libcamera project, said: 'Due to high fragmentation and lack of standardisation, the embedded camera space is subject to painful interoperability issues. Adding camera support in a product is complex and expensive – most often subject to vendor lock-in – when not practically impossible for small actors. Ideas on Board launched the Libcamera project three years ago to address these issues in the Linux mobile, embedded and desktop ecosystems. We have contributed our experience to the Khronos camera exploratory group and are looking forward to continuing collaboration with the industry on a new open standard camera API.'

Opportunities for embedded and AI

By Thomas Lübkemeier, EMVA general manager

To date, the machine vision industry has coped well during the pandemic; it serves a diverse range of vertical markets. However, economic forecasts for 2022 are challenging. Supplies of semiconductors and other components are causing problems for machine vision firms, dampening business prospects. It also remains difficult to assess how the pandemic will unfold in 2022.

In terms of technology, embedded vision and AI remain macro trends in the vision industry. Using neural networks and AI in machine vision is often effective, but it is not the answer for every application. Embedded vision in Industry 4.0 requires a clear understanding of interfaces and software hierarchies. Feeding into these trends, cybersecurity will become increasingly important as a basic requirement for embedded vision systems and AI applications - particularly those with cloud connectivity. More broadly, vision based on embedded platforms and AI will open up enormous opportunities, developing markets far beyond those that use traditional approaches.

Business conference
Running from 12 to 14 May, the 20th EMVA business conference in Brussels boasts an agenda packed with topical talks from industry leaders, alongside many opportunities to network with the people defining the future of machine vision. Presentation topics will give insights into the evolution of the vision market, including industrial cybersecurity, non-visible imaging, artificial intelligence and the future of sensing. More information and registration can be found at: www.business-conference-emva.org.

New members
We are proud to announce that EMVA membership has increased significantly, even during current pandemic uncertainties. No fewer than 16 companies and one institute signed up for membership last year. Diversity marks both their origin and their fields of activity. The new members are headquartered in 10 different countries, while their main operations cover the entire range of machine vision activity – from component manufacturing to distribution, consulting, embedded vision and AI. Furthermore, during the first weeks of 2022, EMVA welcomed Opto Engineering, a specialist in optical imaging technologies based in Mantova, Italy; and Emergent Vision, a Canadian manufacturer of high-speed cameras.

Emberion raises €6m for SWIR nanomaterial imagers

Emberion's CTO and co-founder, Dr Tapani Ryhänen (left)

Finnish firm, Emberion, plans to expand manufacturing and extend the wavelength range of its sensors into the midwave infrared, following investment in its SWIR quantum dot detectors.

Emberion offers visible-to-shortwave-infrared sensors and cameras capable of imaging from 400nm to 2,000nm.

The photodetectors are built by integrating nanomaterials, such as colloidal quantum dots and graphene, on top of a CMOS readout circuit using thin film processes and spin coating. Tuning the nanomaterials extends the sensitivity of the sensor out into the shortwave infrared.

The firm has just launched its VS20 Vis-SWIR camera, a VGA device with a 20µm pixel pitch, operating at 100fps and 120dB dynamic range.

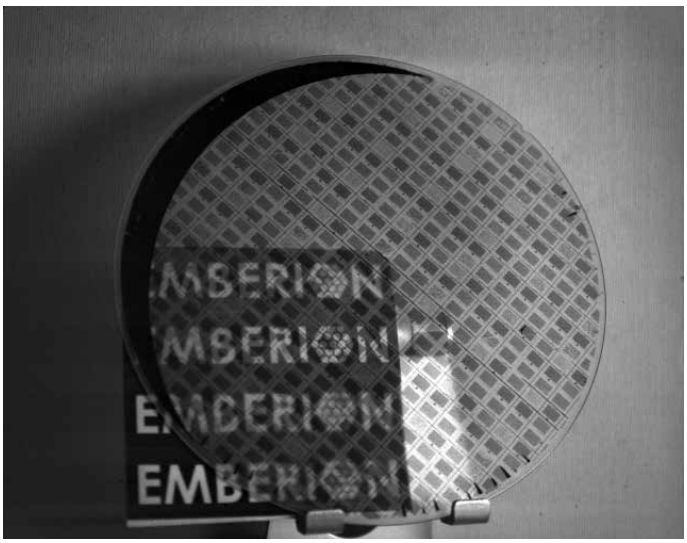
Speaking to *Imaging and Machine Vision Europe*, Jyrki Rosenberg, CEO of Emberion, said: 'We're pleased with the faith the industry has put in us [through the €6m funding]. Our investors see this technology as having wings and really being able to change the market.'

Nanomaterial-based sensors are able to sense over a wider wavelength range than InGaAs sensors, as well as being lower cost. The technology is also highly scalable, with the potential for high-volume production, alongside small pixels and therefore high resolution, as demonstrated by STMicroelectronics' new quantum dot SWIR sensor. InGaAs technology is limited in both scalability and resolution.

Emberion has chosen to focus mainly on industrial machine vision and surveillance at the moment, Rosenberg said. He named plastic sorting – and recycling more broadly – and food inspection as two areas where the firm is seeing interest.

Tapani Ryhänen, the company's CTO, told *Imaging and Machine Vision Europe* that Emberion is investigating nanomaterials to extend the wavelength range out into the midwave infrared. In addition, it has a roadmap to produce megapixel devices,

Emberion



A silicon wafer, which is transparent in the SWIR region, captured with Emberion's VS20 Vis-SWIR camera

Emberion

Surveillance image taken with Emberion's VS20

Emberion

while also working on lower cost and miniaturised packaging for new types of application.

Ryhänen said: 'At the moment, characterising our device performance we can say we have extremely good image quality and we have very high dynamic range compared to InGaAs.

'We are on a par with other quantum dot SWIR imagers on the market in terms of quantum efficiency,' he continued. 'Quantum efficiency depends on the wavelength you're working at; when you extend the wavelength range you get lower quantum efficiency. We have more than 80 per cent QE for visible light, but the same sensor will give a bit over 20 per cent QE at 1,850nm.'

Ryhänen emphasised the reason why there is such interest in nanomaterial-based SWIR technology is that it's scalable. 'The starting point has a cost benefit compared to InGaAs, but also it leads to scalability,' he said. 'We can scale the pixel area and we can fabricate smaller or larger pixels with greater ease, depending on the requirements of the customer.'

Emberion is shipping products to customers for evaluation, and is expecting further demand from them. 'We want to be ready this year to increase production capability to meet this demand,' Rosenberg said.

'We're already at the point where the market will start to shift towards buying quantum dot SWIR sensors'

'We're investing in scaling up production, commercialising our current imagers, and continuing to develop future generations of devices,' he added. 'We do see adoption to be further increased by extending the capabilities of the devices. However, we're already at the point where the market will start to shift [towards buying quantum dot SWIR sensors].'

Emberion is headquartered in Espoo, Finland, but has its sensor development and fabrication centre in Cambridge, UK. It is a partner in the European Commission's Graphene Flagship programme and leads the Graphene Flagship spearhead project, GBIRCAM, to design cheaper and more efficient broadband infrared devices.

The funding round was from Nidoco, Tesi (Finnish Industry Investment) and Verso Capital.

Hitachi to use TriEye SWIR tech for driver assistance

Tier 1 automotive supplier, Hitachi Astemo, is to evaluate a shortwave infrared and 3D sensor from Israeli firm, TriEye, for use in its advanced driver assistance system (ADAS).

TriEye's Sedar – Spectrum enhanced detection and ranging – device provides both HD SWIR imaging and deterministic 3D mapping. Hitachi wants to incorporate Sedar, which was recognised at CES 2022 with an innovation award, into its ADAS system to give 2D and 3D depth information under low-visibility conditions.

The Sedar device is based on TriEye's SWIR CMOS Raven sensor. The technology follows other firms that have built SWIR sensors on CMOS readout circuitry, thereby substantially lowering the price of SWIR imaging compared to InGaAs sensors.

The Raven sensor has a resolution of 1,284 x 960 pixels with a 7µm pixel pitch; it operates from 0.4 to 1.6µm, and can run at 120fps.

Recently, TriEye unveiled a VCSEL-powered SWIR system, integrating its sensor with a 1,350nm vertical-cavity, surface-emitting laser (VCSEL) as an illumination source. The company said the system will provide value for short-range tasks, such as mobile, biometrics, industrial automation and medical.

The Sedar system is designed for longer range in automotive applications. John Nunneley, senior vice president, design engineering, Hitachi Astemo Americas, said: 'We believe TriEye's Sedar can provide autonomous vehicles with the ranging and accurate detection capabilities needed to increase safety and operability under all visibility conditions.'

In November last year, TriEye secured $74m in funding for its SWIR sensing technology.

ST's quantum dot sensor set for volume SWIR imaging

STMicroelectronics unveiled a quantum dot shortwave infrared (SWIR) image sensor at the International Electronic Devices Meeting (IEDM) in San Francisco in December.

The company demonstrated a 1.62µm pixel pitch global shutter SWIR sensor, with a quantum efficiency of 60 per cent and a shutter efficiency of 99.98 per cent at 1,400nm.

The devices were manufactured on 300mm wafers, so suitable for high-volume production at a relatively low cost.

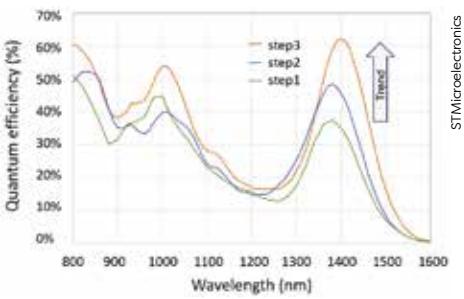
Speaking to *Imaging and Machine Vision Europe*, Jonathan Steckel, director of advanced technology intelligence in imaging at STMicroelectronics, and lead author of the paper, said the cost of the sensor could be down in the single-dollar region, similar to what would be paid for a silicon imager.

Detectors for SWIR imaging have traditionally been made from InGaAs, because the material performs well in this wavelength band, where silicon does not. But InGaAs sensors can cost hundreds or thousands of dollars.

Sensors incorporating colloidal quantum dots (CQDs) can be tuned to be sensitive to light in the shortwave infrared while remaining low-cost.

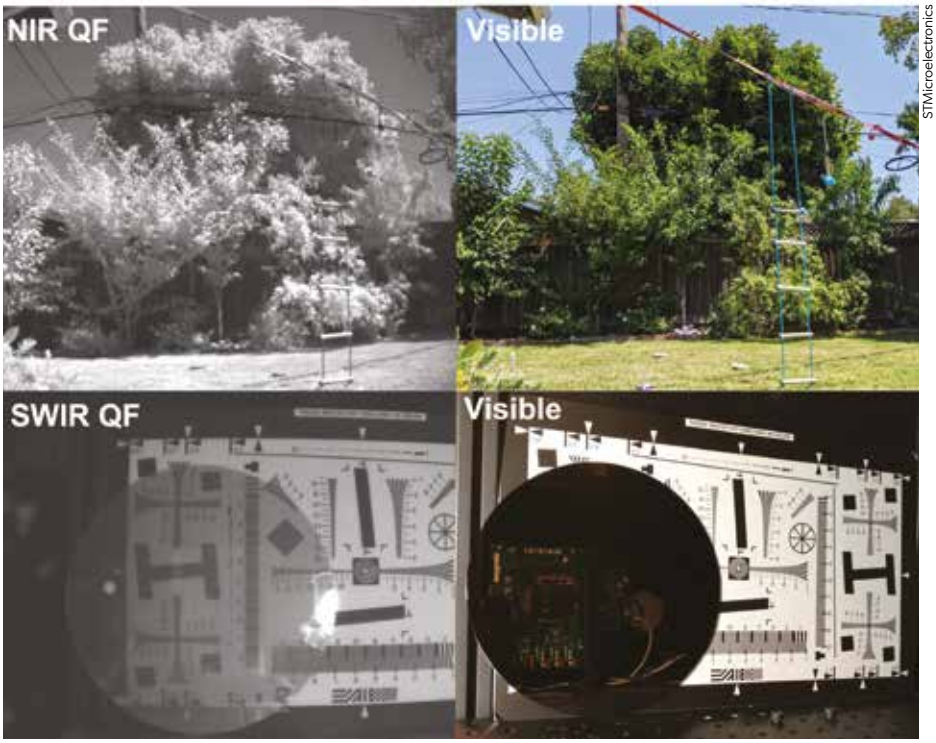
STMicroelectronics' sensor is the latest announcement in the blossoming area of CQDs for SWIR imaging, with commercial CQD sensors available from SWIR Vision Systems, Emberion and Imec, among others.

The ST work, though, shows commitment to high-volume production, and could open up SWIR imaging for consumer electronic devices and other larger volume applications.



STMicroelectronics

Quantum efficiency spectrum for STMicroelectronics' SWIR Quantum Film photodiode showing a peak above 60 per cent with optimised layer thicknesses



STMicroelectronics

Images taken with STMicroelectronics' 940nm NIR Quantum Film sensor (top left), showing electrical wires against dark trees; and a silicon wafer taken with its 1,400nm SWIR QF sensor (bottom left); plus corresponding visible images

'The potential of the technology is that you can essentially do SWIR imaging at silicon cost,' Steckel said.

He added: 'SWIR imaging can become a much larger volume industry, and a more significant industry than what it currently is based on InGaAs technology.' The ST CQD sensor will 'open up a lot of different use-case scenarios that we can't yet define, because people will have access to it.'

STMicroelectronics' technology is based on lead sulphide quantum dot thin films. These are made in solution and the deposition steps integrated within a CMOS semiconductor process, in STMicroelectronics' case within its 300mm fab.

The disadvantage of CQD technology for shortwave infrared is the quantum efficiency is lower than InGaAs sensors. Steckel said ST's quantum dot SWIR image sensor is not a huge leap in performance compared to CQD sensors from other suppliers, but that ST is going to make it available at a significant scale and with the reliability consumer electronic customers demand.

He said there's a lot of effort going into improving the quantum efficiency of CQDs. In academia, Professor Edward Sargent at the University of Toronto has reported 80 per cent quantum efficiency of a CQD photodetector at 1,550nm.

'The potential... is that you can essentially do SWIR imaging at silicon cost'

'In industry, in the next couple of years, we'll probably also be able to develop our technology to hit higher quantum efficiencies, upwards of 70 to 80 per cent,' Steckel said. 'Then it would create more of a value-add, and more of a gap between what silicon can do versus what CQD can do in the NIR, and also close the gap between what InGaAs can do versus CQD technology in the SWIR.'

As part of its IEDM paper, STMicroelectronics showed its device met the current consumer electronics industry standard for reliability, although Steckel added ST is working on higher temperature stability, so that it can address more demanding applications.

The firm plans to provide evaluation kits to customers soon.

Quantum dots to spark new SWIR wave

Imec's **Paweł Malinowski** looks at the SWIR imaging landscape as activity around thin film SWIR sensors intensifies

Acquiring information in the shortwave infrared (SWIR) wavelength range has been limited to niche applications for decades. SWIR is used in the military to identify targets in adverse lighting conditions, for instance; in machine vision for tasks such as solar cell inspection; and in scientific and space systems. These are typically high-end applications – the cumulative number of units sold each year measures in the tens of thousands.

SWIR cameras are traditionally based on focal plane arrays, with a resolution rarely exceeding 1 megapixel and a pixel size an order of magnitude larger than that of the CMOS image sensors (CIS) used in consumer devices. A typical pitch in a SWIR detector is 15-20µm versus sub-micron pixels for CIS. Imagers are made by hybrid bonding detector chips based on III-V materials – usually InGaAs, sometimes HgCdTe – to the readout chip using solder bump connections and die-to-die flip-chip techniques. All those elements in the fabrication process result in a very high price point for these sensors, easily exceeding several thousand euros per chip.

A recent innovation reported by Sony in 2019 uses Cu-Cu bonding of an InGaAs detector chip; this scaled down the pixel pitch to 5µm. The IMX990 and IMX991 chips are finding their way into more products, particularly in machine vision, as they enable higher image quality and easier integration. Even with a premium price point, this sensor family opens up SWIR imaging to new use cases.

SWIR sensors based on thin films promise to lower the implementation barrier even further, with quantum dots playing the lead role as a new type of absorber. The technology has been investigated for almost two decades; the first academic papers were published at the beginning of the 21st century by Professor Sargent's group at the University of Toronto. Pioneering work has taken place since then.

The first products are now being brought to market. Emberion recently announced its VS20 camera with a spectral range from 400 to 2,000nm. Meanwhile, SWIR Vision Systems offers its Acuros series of cameras with the highest SWIR resolution on the market (1,920 x 1,080 pixels). These are disruptive products in the infrared imaging field, proving that quantum dot (QD) technology is sufficiently mature to deploy commercial products.

'STMicroelectronics' announcement should reassure the industry that quantum dot image sensors are a credible technology'

In parallel, research centres such as Imec continue to explore the QD pixel stacks, readout architectures and integration process to improve performance and enable upscaled fabrication. At the same time, new application fields are opening up for end-users who hadn't considered SWIR imaging due to cost, size and complexity well beyond their reach.

In 2019, Imec presented a 5µm pixel pitch QD SWIR image sensor. A year later, they produced a 1.82µm proof-of-concept device – both state-of-the-art pixel density for SWIR image sensors at the time of introduction.

Now, at the 67th International Electron Devices Meeting (IEDM) in December, the tone-setting event for the semiconductor industry, STMicroelectronics has announced QD image sensors. The 1.62µm pixel pitch sets a new record; an external quantum efficiency of 60 per cent at 1,400nm inches ever closer to the values found in incumbent technologies.

The most exciting feature is that these results come from chips fabricated using a 300mm wafer platform – QD technology has lead to significant strides in making it ready to manufacture. Upscaling to a wafer-level process promises extraordinary throughput and therefore cost evolution. New sensor products based on this process will disrupt the market further, acting as a critical enabler for SWIR imaging in previously impractial applications such as consumer products.

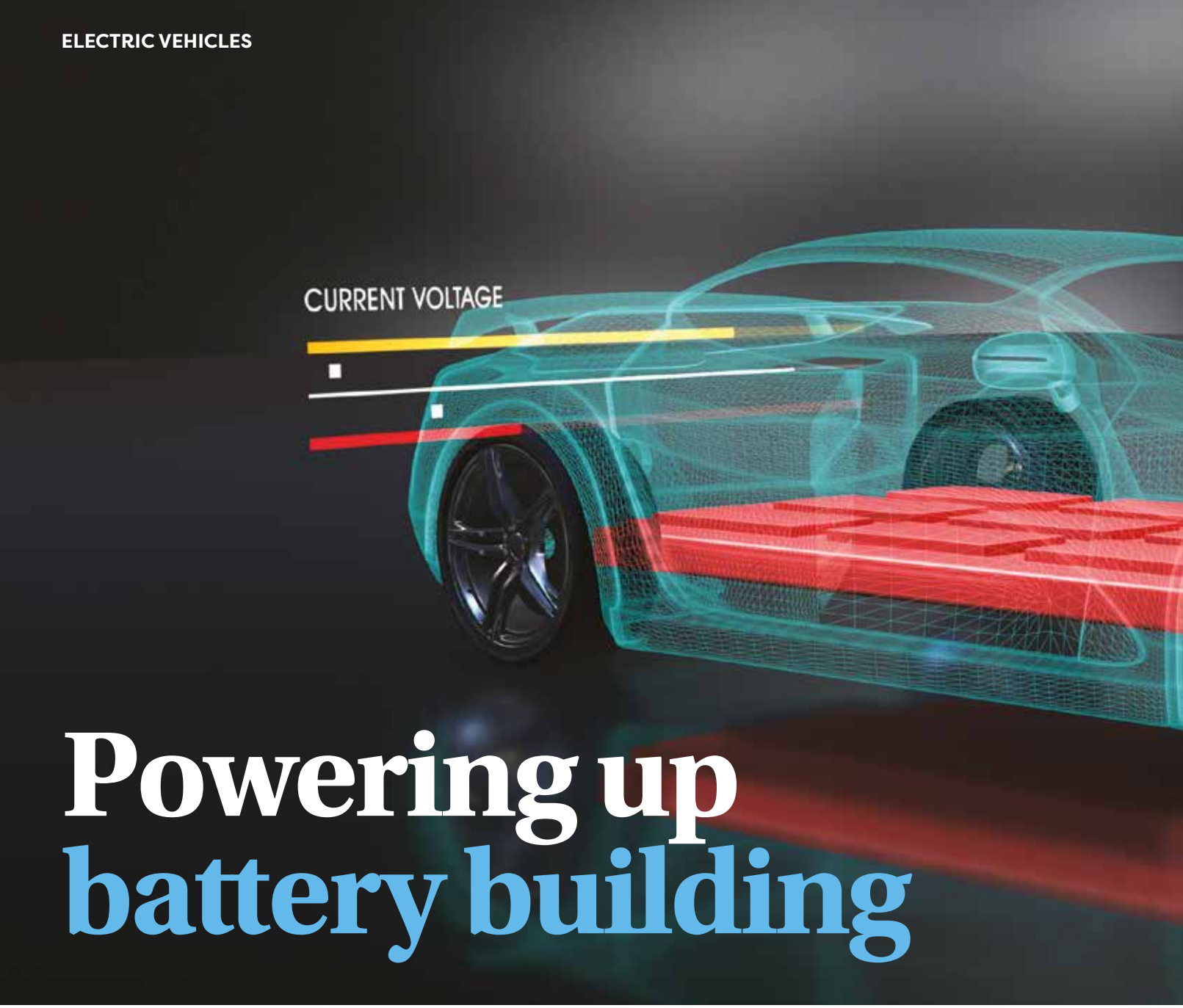
Imaging in the SWIR band offers advantages ranging from improved eye safety for devices using laser light like lidar – eye sensitivity to radiation at wavelengths above 1,400nm is around six orders of magnitude lower than that at 940nm – to low-light imaging and cameras that can see through adverse weather conditions.

Looking forward, there are still technological challenges to address. Moving away from lead sulphide-based QDs to lead-free material systems will encourage more players to accept this type of sensor. Improving deposition throughput of the quantum dot layers through one-step coating – instead of the standard layer-by-layer coating used to achieve the desired final thickness of the absorber – will significantly increase the takt time in volume production.

Moreover, thorough investigation of reliability metrics according to industry standards will allow further iterations of QD improvement to optimise long-term stability, enabling even harsh applications such as those required by the automotive sector.

STMicroelectronics' announcement at IEDM should reassure the industry that quantum dot image sensors are a credible technology with excellent potential, scalable to manufacturing in semiconductor foundries. This should fuel further investment in researching these fascinating devices, sparking a wave of applications for more accessible SWIR camera systems.

Paweł Malinowski is programme manager at Belgian R&D institute Imec. He has more than 10 years' experience in developing photonics technologies and is currently working in the institute's thin-film electronics group.



Powering up battery building

David Stuart asks where the opportunities lie for vision firms selling into electric vehicle battery production

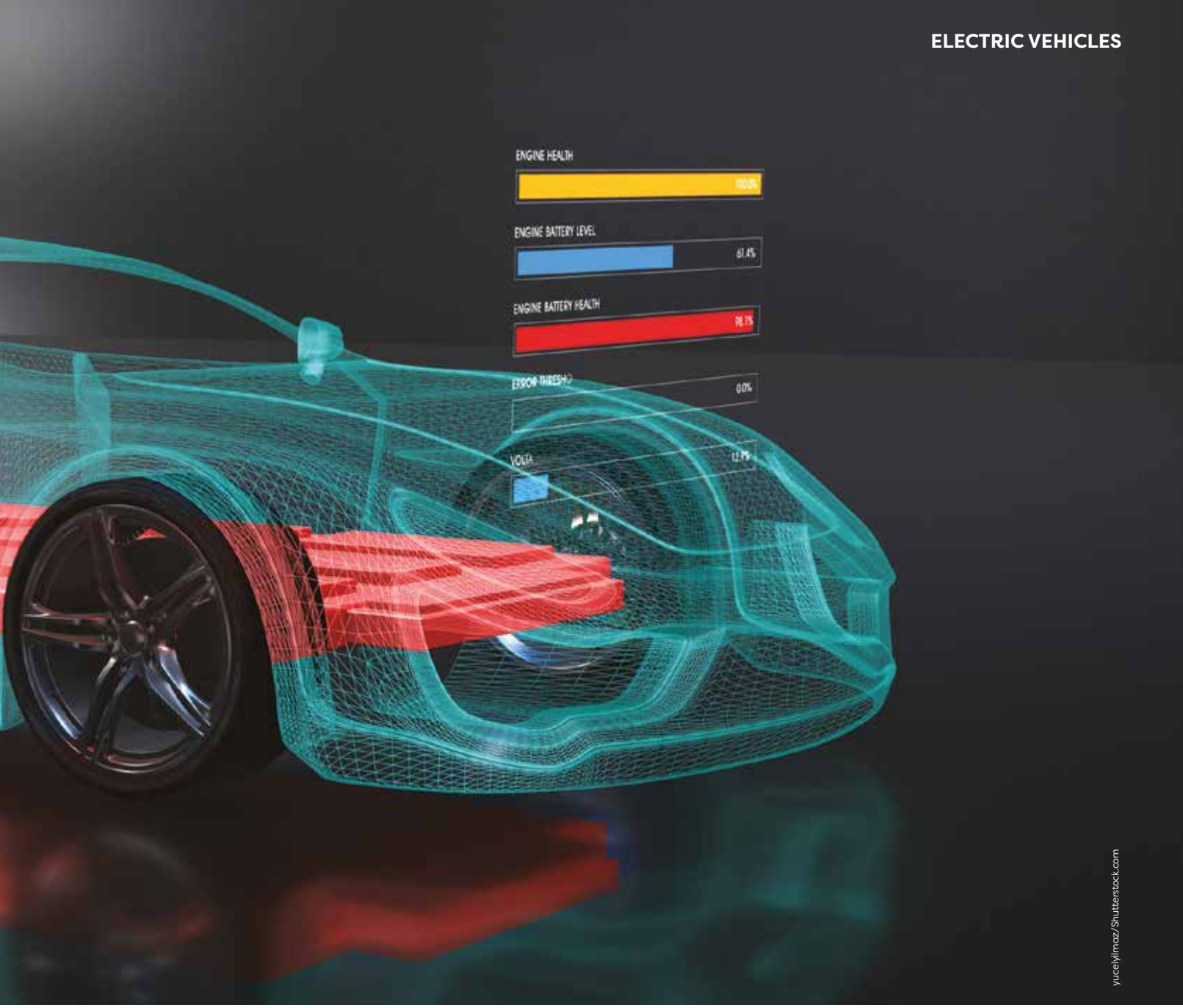
The move to plug-in electric vehicles (EVs) is gathering pace as governments and individuals recognise the importance of clean air for both people and the planet. While Europe leads the world for market penetration of EVs, it is China that dominates the market for EV battery production, with more than 70 per cent of the world's current manufacturing capacity. Fredrik Fager, business development director for Sick Asia-Pacific, and leader of the machine vision teams in China, based in Shanghai, spoke to *Imaging and Machine Vision Europe* about some of the opportunities and challenges for machine vision in EV battery production in China, and its implications for Europe and the rest of the world.

The rapidly growing market for EV batteries brings with it a lot of opportunities for machine vision in battery production. As Fager explained, there are not only machine vision opportunities throughout the battery production process, but also onwards through the lifecycle of batteries.

EV batteries consist of cells, which are put into modules, which are then put into battery packs, and finally these packs are put into cars and vehicles. But that doesn't have to be the end of the process for machine vision for EV batteries. In China there are battery swap stations, where a battery can be swapped rather than charged up.

'There's a tremendous amount of vision applications, from battery cells up to the bigger battery packs,' Fager said. These range from inspecting the process of filling battery cells with electrolytes and checking for defects like pinholes, to looking for foreign objects on battery packs. Fager said the biggest potential for using automated inspection is in battery cells, then modules, and then packs, but that there are now more opportunities appearing in module and pack inspection.

'It's currently very dynamic and companies are competing to gain early market share,' he said. 'Since the industry is still developing, there is room for improvement in many of the inspection steps, which creates many opportunities.



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The end users have very similar approaches and technologies, but manufacturing processes differ slightly, and what the end users or OEMs choose to automate and how they do it also varies. This is converging more and more to some sort of best practice, but new applications and iterative improvement opportunities keep coming up.'

He added: 'In a few years, when EVs are more common on public roads, automatic battery recycling will surely bring another set of challenges that need to be solved with machine vision.'

It's not just technological challenges that must be faced in China, it's also a very competitive market. China has a lot of machine vision companies, many of which have their own software and camera brands. However, as Fager explained, as EV batteries are an evolving market, there's not market dominance yet by any large players, and smaller, agile companies are able to make inroads. This is something that isn't always possible with more mature markets.

'If you look at the companies that have been dominating the machine vision space in the past, they have had a quite nice position in, for instance, the electronics or automotive industry for a long time,' he said. 'They have benefited from good brand recognition and existing supplier agreements.' He went on to explain that even though a smaller firm might have the best technology and can solve an application better than anyone else, just as fast, and for the same price, it still doesn't necessarily win projects, because other companies are so well established in these industries.

The EV battery industry is relatively new and therefore different. 'It is a great opportunity,' he continued, 'but you have to be quick on your feet, you have to be willing to pivot if necessary, and that's quite a big challenge for many companies. But if you come from a solid technical base, and you have been selling machine vision for some time, then I think it can suit you very well.'

'Supplier agreements are still not set in stone between established vision companies and battery manufacturers, so others have a chance'

He said battery inspection is a good fit for Sick, because it has a lot of experience and has invested a lot into machine vision. →

asharkyu/Shutterstock.com

Electric car lithium battery pack and power connections

→ 'We can win [business] to a much greater extent [in battery production], because the big battery companies don't really have a preference [in vision supplier] yet,' he noted. 'Supplier agreements are still not set in stone between the most established vision companies and the big battery manufacturers, so others have a fairer chance of winning.'

The area where Sick feels it is most competitive is with 3D sensors, according to Fager. '2D is extremely competitive in China, so to enter there when there are so many companies that can do everything for a very low price is quite challenging. Currently, we focus more on 3D machine vision, since this is where we believe we are most competitive, thanks to market-leading products. But, of course, we also see a lot of opportunities in the 2D vision space and we do not limit ourselves to 3D.'

'If vision integrators and machine builders in Europe want to remain competitive, they must adapt quickly to compete'

Fager said that many of the 3D sensors Sick has released during the past two years in China has been a direct result of the demand in the EV battery industry. 'Thanks to our Ranger3-based sensor technology, local competence and a streamlined development approach, we are often able to provide integrated 3D camera prototypes within one month,' he said. 'This has helped our customers meet their harsh deadlines, while at the same time ensuring peak performance in terms of inspection speed, throughput and data quality.'

Sick has also developed a number of software packages through its EzR and

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Electric vehicle battery module

Sick AppSpace image processing software, which target the EV battery sector. Fager said more than two thirds of Sick's Chinese customers use the firm's image processing software, and in 2022 more emphasis will be placed on developing these platforms further, especially around deep learning.

As Fager explained, when it comes to software, the big focus is on ease of use; without ease of use it's difficult to win business in China, because everything is moving so fast and the buying cycle is so short. He said it's a race between the big battery producers to be number one, and it's such a lucrative area that they want to automate as quickly as possible.

As the market for EV batteries continues to expand, battery factories are inevitably being planned all over the world, but as Fager notes, without the whole ecosystem and competence that is already established in China, it is going to be difficult for some companies to compete.

'If you want to go into battery [production], you have to be prepared to take up the fight with the Chinese'

'When manufacturing later shifts from China to other parts of the world, local supply chains of integrators and OEMs need to be established too,' Fager said. 'Battery manufacturers are already looking towards China for this [integrator and OEM supply chains], and the competence around EV battery production has ramped up fast in the past few years. I do have some doubts about how the European battery companies can be competitive in a short time, and if vision integrators and machine builders in Europe want to remain competitive, they must adapt quickly to compete with the already experienced and fast-paced Chinese. If not, then the big battery companies will favour OEMs and line builders from China. And, besides already having solutions to tackle most problems, they also do things at lower prices than we may be used to in the West.

'Of course, it's not cheap to shift big machines from China to Europe either, but the development cost in China is just so much lower, and also the supply chain has been built up for many years there,' he continued. 'Moreover, more and more Chinese machine vision companies set up branch offices abroad just to cater for the demand from the EV battery manufacturing industry. This is a real challenge that European machine vision companies need to face in the coming years. If you want to go into battery [production], you have to be prepared to take up the fight with the Chinese, and fully understand the behaviour of your competition.'

High-speed stereo system inspects battery foils

Scientists from the Austrian Institute of Technology (AIT) have developed an inspection system able to detect flaws in battery foils at production speeds of 2,000mm/s.

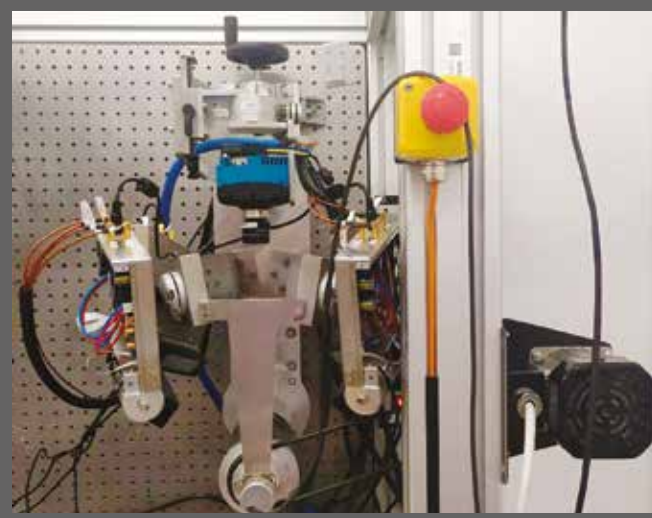
During trials, the AIT scientists showed that its system – based on photometric stereo surface reconstruction – can identify common defects occurring in the coating process of battery electrodes.

Battery electrodes are made by applying a slurry of electrochemically active materials, binders, conductive additives and solvents onto a metal substrate foil. The electrical characteristics of battery cells will depend on the quality of the coating, which ideally should be fine-grained and cover the substrate area evenly.

The AIT's inspection system is comprised of four line-light sources, illuminating the substrate from four directions; a high-speed industrial camera from Mikrotron viewing the material from above; an FPGA-based trigger that synchronises the strobes with the camera acquisition; and a PC for coordinating image data acquisition and computing the foil surface representation.

The FPGA-based controller developed by AIT synchronises control of lights and camera acquisition with material motion. First, the trigger hardware decimates the pulses from an optical encoder with 5µm increments to frame trigger pulses with 50µm increments, thus defining the resolution in transport direction as 50µm per pixel. Second, for each frame-trigger pulse, the controller switches on a different light while the other lights are off, and triggers an image acquisition by the camera. To acquire each object point under four different illumination conditions, four rows of the camera's pixel matrix are read out per frame trigger.

The Mikrotron EoSens 4CXP area scan monochrome camera used has a 2,336 x 1,728-pixel resolution, 7µm pitch, and four-channel CXP-6 output. It was equipped with a Schneider-Kreuznach Xenoplan 2.0/28 lens with a 29.29mm focal length, and mounted with 226mm working distance for a magnification of 0.14.



AIT's system prototype attached to a roll simulator

The optical resolution of the camera system was 50µm per pixel, which is equal to the resolution in transport direction. Using this configuration, a field-of-view of approximately 116mm perpendicular to transport direction, and 200µm in the transport direction, was achieved.

The system was able to identify a range of defects during testing, such as missing coating, coating inhomogeneities, pinholes, agglomerations, cavities and cracks.

While the scientists focused on electrodes for their study, the system can be repurposed for defect detection for other materials, such as steel surfaces.

Fishful thinking

Tim Reynolds on some of the ways imaging is used to farm fish

Around half of all fish consumed globally are now farmed. The amount of wild fish caught has remained at roughly 90 million tonnes per year since the 1990s, with the United Nations Food and Agriculture Organisation estimating that one-third of global wild stocks are already being fished beyond sustainable limits. In the case of salmon, almost three-quarters are farmed, with major production centres in Norway, Scotland, Chile and Canada. Farms are looking for ways to improve productivity, but there are significant concerns over the environmental impact caused by waste feed and the transmission of diseases to native fish populations. Imaging can help with both, making farms more productive and reducing their environmental impact.

'The industry's biggest expense is feed,' said Lief Johannesen, head of R&D at JT Electric. 'Optimising feed can minimise costs and have a big impact on environmental issues, reducing the quantity of wasted feed.'

JT Electric is based in the Faroe Islands and supplies electrical products to the aquaculture sector – a term that covers fish farming but also the farming of other aquatic organisms like shellfish and algae. JT Electric's FishFeeder system uses cameras – including an upward facing camera – deployed in and around fish pens that may be 50 metres deep.

'The system uses computer vision algorithms to analyse images coming from cameras in the pens,' explained Johannesen. 'The software can differentiate between pellets and fish, analyse patterns on screen and feed back to the system.'

Using the system, operators can adjust the feed mechanism to minimise 'drop through' of feed, maximising feed conversion rates.

Johannesen said the computer vision system is there to help get the best out of the facilities. Even a small increase in feed efficiency can make a big difference to a fish farm's bottom line and environmental impact.

Digital aquaculture

As for most industrial sectors, digitisation is a hot topic along the supply chain from fish farm to fork. The aquaculture sector is in the early stage of transformation when it comes to technologies such as artificial intelligence, big data, machine learning and vision analysis. The industry needs to develop an understanding of where, how and if new digital technologies can be used.

Johannesen pointed out that many farms are in remote areas and subject to bad weather, requiring robust digital communications infrastructure. Full digital developments may be more rapid in land-based fish farms where communications are guaranteed.

Nevertheless, some remarkable developments have been achieved. Aquaculture start-up Aquabyte is selling machine-learning technology that claims to improve fish welfare and overall farm efficiency.

Started in his bathtub by CEO Bryton Shang, Aquabyte is now an established software company with a global presence.

Writing on the company blog, Shang described how he adapted the machine-learning technologies he had previously applied to stock market trading and cancer diagnostics.

In the bathroom of his home in San Francisco, he was able to measure the distance to robot fish and develop a 3D model that successfully estimated their weight using two cameras. But a Californian bathtub is a world away from the real-life conditions of a fish farm pen with tens of thousands of fish.

Combining the innovation culture of Silicon Valley with expertise from the Norwegian aquaculture sector, Aquabyte has developed an automatic weight measurement system, enabling daily, continuous measurement of several thousand fish with an accuracy of 98 per cent.

> 'Optimising feed can minimise costs and also have a big impact on environmental issues'

This close monitoring of fish growth and health enables farms to provide more precise slaughter estimates.

The company has also developed automated lice counting software that runs with the same imaging hardware. Sea lice are not harmful to humans, but the lesions they cause, even in minor infestations, can render the salmon unmarketable. Severe infestations can lead to secondary infections and even mass mortality in the farm.

The global economic impact of sea lice →

Seaweed is grown on ropes, the moorings and position of which can be tracked by a vision system

‘Recent applications [using hyperspectral imaging]... include identification of nematodes in white fish and assessing shelf-life’

→ infestations on the industry is of the order of $500 million annually. And because sea lice also affect local wild fish stocks, the issue has a knock-on environmental impact.

Aquabyte’s lice counting application enables producers to get a better, more accurate overview of the sea lice situation in their pens without increased handling of the fish.

Injection at pace

Another aspect of fish health and welfare in aquaculture is immunising stock against disease. Vaccinating large numbers of fish – usually by immersion or injection – is a challenging task.

The injection route is a highly skilled manual process, but new mechanised systems can deliver a combination of vaccine formulations accurately and consistently. These are able to easily export all data on the vaccinations delivered, size and distribution.

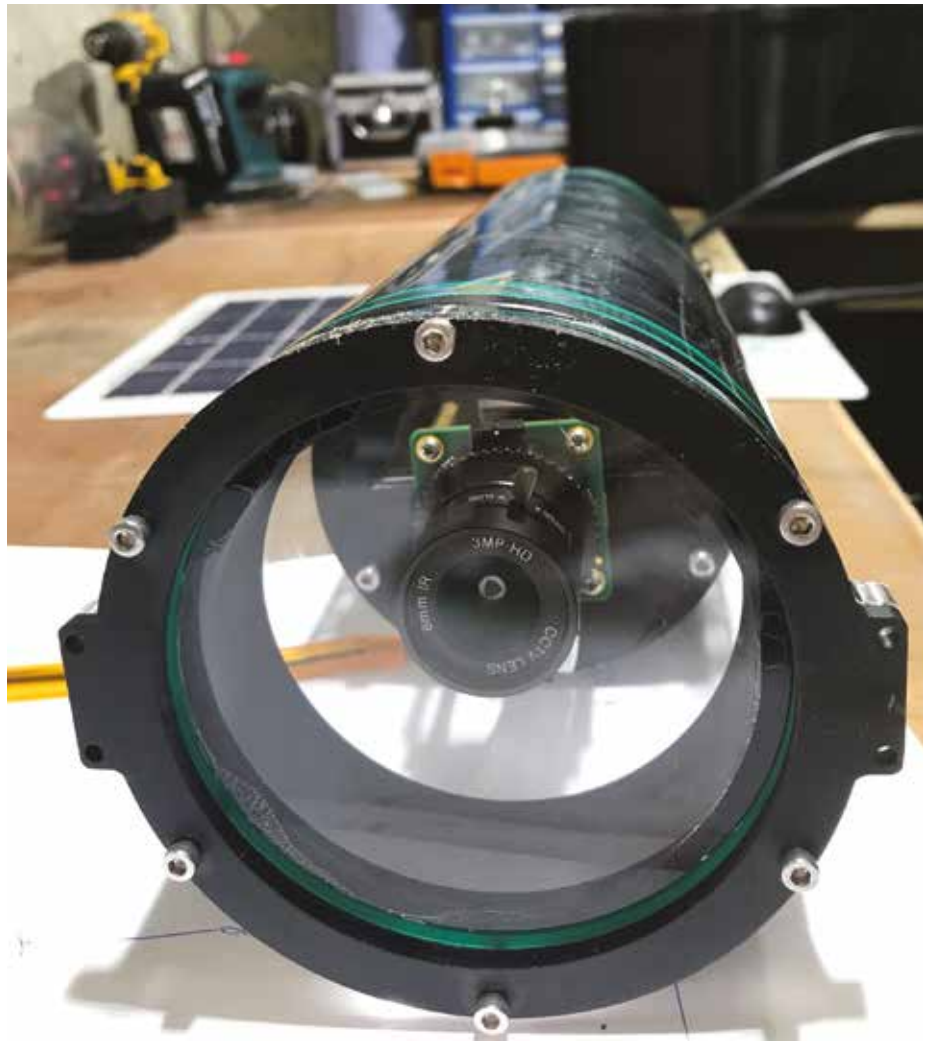
For example, the Pharmaq Fishteq range of equipment uses a machine vision system to determine the inoculation site on each target fish. The image recognition software can cope with a wide range of fish sizes (120 to 250mm or 20 to 150g) and a variety of species. It can determine precisely where the injection site should be to within +/- 0.3mm, with a dose volume accuracy of +/- 2 per cent. The machine can deliver up to three vaccines simultaneously at two different injection sites.

All the Pharmaq models can vaccinate up to 8,500 fish per hour. This minimises extra handling of the fish, leading to improved fish welfare and production economics.

Filleting inspection

Vision systems have multiple applications along the fish processing chain. The Maritech Eye, from Norwegian software firm, Maritech, is designed for automated quality control of fish fillets. It was launched in 2020 and is the result of a collaboration with HySpex, the hyperspectral imaging arm of Norsk Elektro Optikk (NEO) and Nofima, the Norwegian food research institute.

‘The relationship with NEO started in 2003 to 2004,’ recalled senior Nofima scientist Karsten Heia. ‘NEO were producing high-end hyperspectral cameras – mainly for military applications – but they were affordable and therefore applicable for industrial uses.’



PEBL

Plant Ecology Beyond Land has developed a camera system for monitoring cultivated seaweed

Heia continued: ‘The system is based on Nofima research funded by the Norwegian Seafood Research Fund to increase the export value of the fishing sector, finding new solutions for aquaculture and wild fish.’

The original application analysed blood content in unprocessed whole white fish, determining quality before cutting. To do this it used a Baldur hyperspectral camera from HySpex to measure the amount of blood in white fish fillets – a marker for quality grading.

The device can be adapted for other applications. Just before Christmas last year, a Maritech Eye was installed at Mowi Consumer Products UK to enhance the quality assessment of its smoked salmon. It uses high spatial resolution to spot blood leading to dark marks – often rejected by smoked salmon consumers. The machine enables the grader to spot and sort at industrial speed, fully documenting the quality of each unique fish fillet processed. It moves quality assessment onto the production line, rather than relying on sampling and the uncertainty of offline assessment.

‘Recent applications we have worked on [using hyperspectral imaging] include identification of nematodes in white fish and assessing potential shelf-life,’ said Heia. The temperature profile history of a fish from net or pen to processing has a major impact on its shelf life. Monitoring the oxidation of haemoglobin in fish blood trains the system to determine the freshness of the fish – in particular, whether a breach of the cold chain has occurred.

Other uses might include analysis of fatty acid content in salmon, or using a diffuse reflectance light setup to assess for fish welfare indicators such as damaged or bleeding fins.

‘We are continually developing the camera to make it better, faster and more light sensitive,’ said Trond Løke, CEO

Maritech and HySpex

The Maritech Eye system uses hyperspectral imaging to gauge the quality of filleted fish

of HySpex. 'In the near future, we are extending our spectral range into the shortwave infrared up to 2.5µm wavelength.'

Løke added: 'With our camera hardware and the [software] models from Nofima it is relatively simple to add new features through software updates, covering other quality parameters as required. It used to take years to develop, validate and verify a model - now it is much swifter.'

Per Alfred Nordaune Holte, vice president of technical solutions at Maritech, commented: 'The development cycle for new applications can now be a matter of months. It is now a very structured approach.'

Not just fish

Of course, aquaculture is about more than fish. A Welsh company seeks to empower coastal communities using imaging to develop sustainable ways to cultivate, monitor and protect native seaweed species.

Plant Ecology Beyond Land (PEBL) is developing SeaLens, an autonomous monitoring system for small and medium-sized aquaculture organisations. Modular in design, it integrates sensors to monitor various parameters, such as seawater temperature, salinity and pH with video and imagery inputs.

Christian Berger is CEO. He described a seaweed farm as essentially a series of buoys in the water. PEBL is working on systems to monitor how storms and other natural phenomena impact them. The key elements are a waterproof camera with filters to optimise contrast and software that identifies problems with the farm.

Monitoring the farms both above and below water, image analysis tracks certain rope positions and moorings, indicating potential issues within the farm.

Storm damage can be a danger to animals – particularly marine mammals such as dolphins and porpoises. If moorings are loosened, then the ropes may entangle these animals. PEBL's work on ecological monitoring is funded by the World Wildlife Fund.

The equipment also monitors the cultivated seaweed, analysing growth rates and detecting disease. Regular scanning enables calculation of the total biomass in the facility. This is useful to understand growth factors but can also help monitor how much biomass is lost to the ocean due to storm damage. Understanding the fate of seaweed may become another important sustainability factor for aquaculture, as the carbon may be effectively sequestered in the deep ocean.

'The temperature profile history of a fish from net or pen to processing has a major impact on its shelf life'

Berger said that adding seaweed within salmon farms would serve to naturally remove excess nitrates, providing more oxygen. For a truly sustainable future, integrating seaweed cultivation and fish farms may be a win-win situation for the aquaculture industry.

A sense of purpose

A look at some of the latest image sensors for industrial vision

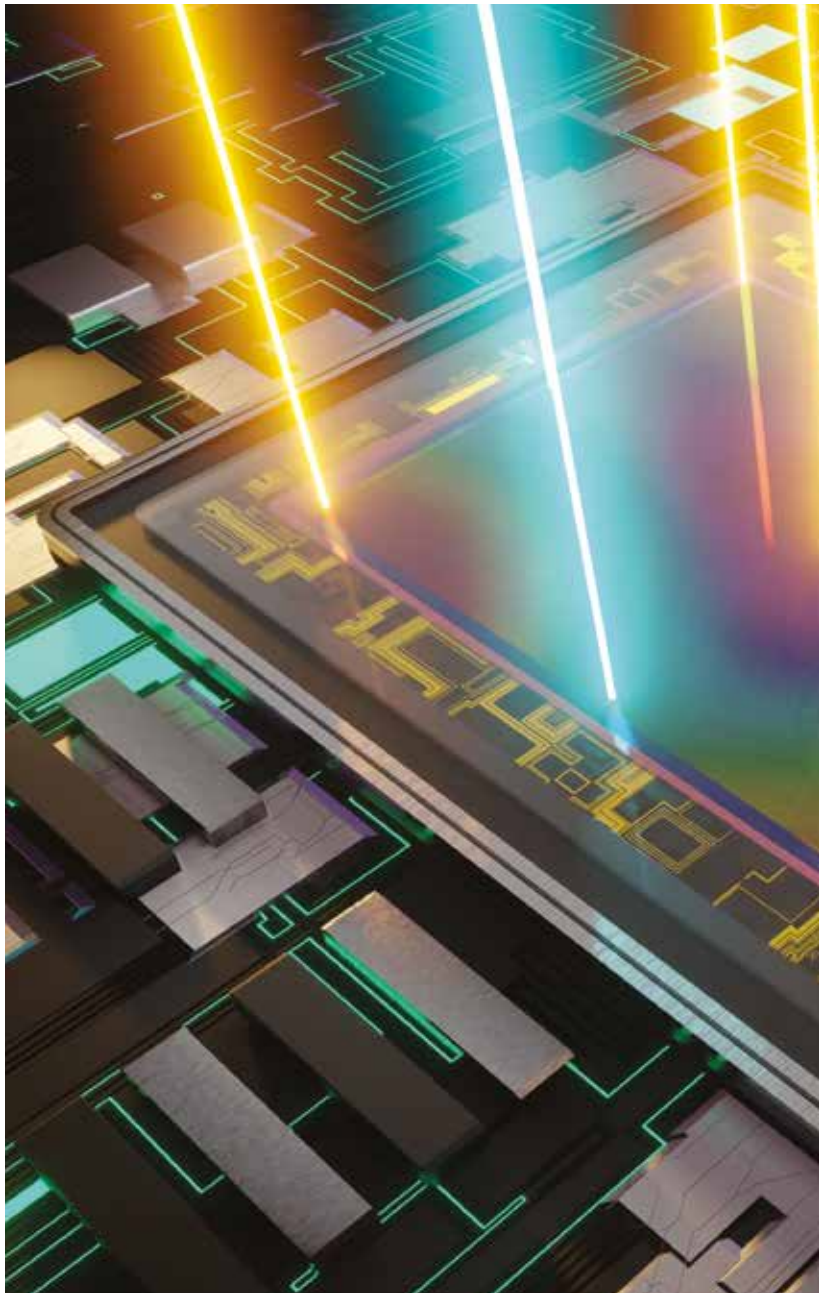


Image sensors convert light into electrical signals. Scientific and industrial cameras used to rely on charged coupled device (CCD) detectors – and there still are areas in astronomy and scientific imaging where CCDs are used – but now most machine vision cameras will integrate a complementary metal-oxide semiconductor (CMOS) detector.

All the investment has been in CMOS technology for mobile phones, and the relatively niche market of industrial imaging has ridden on the coattails of advances being made in CMOS. Sony, which dominates the image sensor market, has stopped producing CCDs entirely.

Sensors for industrial imaging are global shutter to freeze motion, and usually have larger pixels than sensors found in mobile phones. Smaller pixels mean more can be squeezed onto a sensor, leading to higher resolution, but this is at the expense of other performance characteristics – the noise increases with smaller pixels and the full well capacity is lower.

The trends, however, follow the investment being made in consumer device imaging, which tends to be for smaller pixels. It's not just about pixel size though, and the machine vision sector will benefit from other advances being made in sensor technology for mobile phones, and now to a certain extent imaging for the automotive sector, for driver assistance. Technology for 3D ranging through advances in lidar, for imaging in the shortwave infrared, and for event-based or neuromorphic sensing, are all progressing and all have application in machine vision.

Commercial products

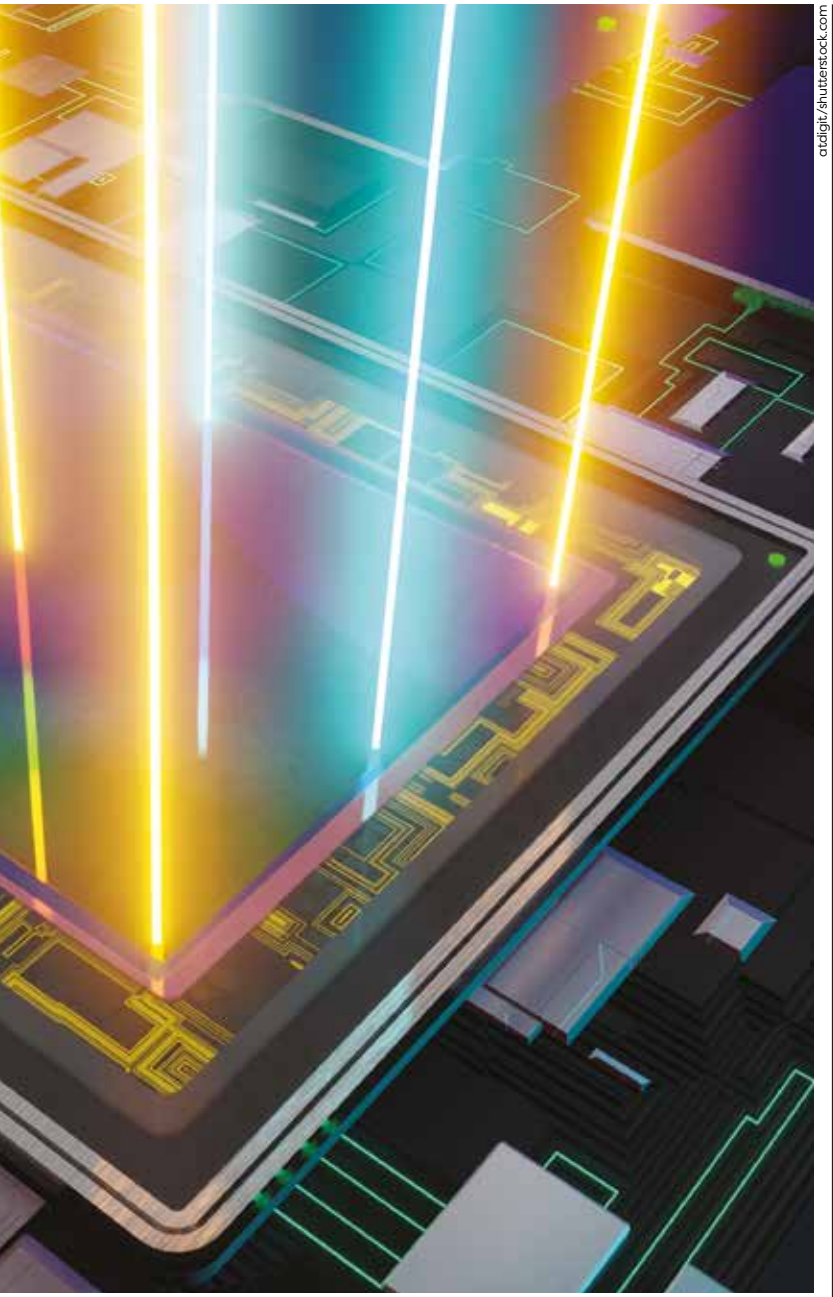
When it comes to commercial offerings, **Sony**'s Pregius sensors are used widely in the machine vision industry, and are available from a number of distributors. Recently, **Framos** announced the availability of the IMX548 and IMX568 5.1-megapixel Pregius S sensors. These 1/1.8-type, global shutter sensors are available in monochrome or colour.

The IMX548 with SLVS interface has a frame rate of up to 114 fps with 8 bits in all-pixel scan mode. The IMX568 supports the Mipi CSI-2 interface and achieves 96 fps at 8 bits. Both sensors support multiple readout modes: all-pixel scan mode, vertical or horizontal 1/2 subsampling mode, 2x2 FD binning mode, and various ROI settings.

Framos now also offers Sony IMX536, IMX546, and IMX566 sensors for factory automation, ITS and embedded vision. The IMX536 is a high-speed variant with SLVS/SLVS-EC interface; it reaches a frame rate of up to 194 fps with 8 bits in all-pixel scan mode. The IMX546 also has an SLVS/SLVS-EC interface and achieves 91 fps at 8 bits. Its resolution makes it suitable for scenarios requiring full HD displays – for example, in factory automation and ITS.

When it comes to event-based sensors, **Macnica ATD Europe** offers the IMX636 and IMX637 sensors from Sony, developed with event-based imaging firm Prophesee. Event-based sensors can achieve high-speed data output with low latency by limiting the output data to luminance changes from each pixel, combined with information on pixel position coordinates and time. Only the pixels that have detected a change in luminance for the object can output data, allowing the sensor to immediately detect the luminance changes at high speed, with low latency, and at high temporal resolution while operating with low power consumption.

Prophesee has released an evaluation kit for the IMX636 and IMX637 sensors. The kit gives developers access to the



atdigit/shutterstock.com

sensors, which feature a 4.86µm pixel pitch and 1,280 x 720 pixel resolution for the IMX636. This kit is ideal for full performance evaluation, supporting full sensor bandwidth of up to 3Gb/s via a USB 3 interface.

Another recent development from Sony is a large-format 56.73mm diagonal CMOS image sensor, IMX661, for industrial equipment with a global shutter function and an effective pixel count of 127.68 megapixels. It has an optical size nearly 10 times larger than the common 1.1-type image sensor.

Also recently announced is the IMX487, a 2/3-type CMOS image sensor for industrial equipment, which is sensitive to UV light. It delivers a high level of UV sensitivity and high-quality image with minimal noise, thanks to components specialised for the UV wavelength and a unique light-receiving unit structure.

Sony's IMX990 and IMX991 devices are its latest shortwave infrared sensors. These detectors have a small pixel for an InGaAs sensor at 5µm, which results in a very compact package design. The IMX990 is the higher resolution version at SXGA, 1,296 x 1,032 pixels. It transmits data at 130 fps at 8 bits, 120 fps at 10 bits and 70 fps at 12 bits.

The latest shortwave infrared detector from **Andanta** is an uncooled InGaAs detector with a spatial resolution of 64 x 64 pixels, a pixel size of 40µm, and an active sensor area of 2.56 x 2.56mm. A 32-pin ceramic LCC design was chosen to package the sensor.

Sticking with imaging in the infrared region, **Lynred** recently enhanced the capabilities across its range of 12µm thermal infrared detectors. These 12µm pixel pitch sensors, based on microbolometer technology, have a noise equivalent temperature difference (NETD) performance of 40 or 50mK.

Other new sensor technologies include **Gpixel**'s time-of-flight sensor for 3D imaging. The GTOF0503 sensor features a 5µm three-tap iToF pixel, incorporating an array with a resolution of 640 x 480 pixels. The sensor was fabricated using Tower Semiconductor's 65nm pixel-level stacked backside illuminated CMOS sensor technology, made in Tower's Uozo, Japan, facility.

Hamamatsu Photonics offers a range of 3D time-of-flight back-thinned image sensors. Through back-thinning, the sensors deliver high sensitivity in the near infrared region. Active circuitry improves the tolerance to background light and makes this new range of distance sensors ideal for measurement applications, including hygiene management, measurement for social distancing and remote operations.

OmniVision Technologies' OH0TA OVMed medical image sensor has a package size of just 0.55 x 0.55mm, featuring a 1.0µm pixel and a 1/31-inch optical format. It reaches an RGB resolution of 400 x 400 pixels at 30 fps, with power consumption of 20mW. This allows designers to add ultra-compact visualisation to single-use and reusable endoscopes, as well as catheters and guidewires, with an outer diameter of 1 to 2mm.

One of the latest global shutter sensors from **On Semiconductor** is the AR0234CS 2.3-megapixel CMOS device. It can capture 1,080p video and single frames operating up to 120 fps. The low noise and low-light response

'All the investment has been in CMOS technology for mobile phones'

make it suitable for applications across consumer, commercial and industrial IoT, and the extended operating temperature range means it can be deployed outdoors.

Finally, new from **Teledyne e2v** is the Topaz series of industrial CMOS sensors with 2 megapixel and 1.5 megapixel resolution devices. These 1,920 x 1,080-pixel and 1,920 x 8,00-pixel sensors are housed in a 4.45mm-wide, chip-scale package. The sensors have an optical array centre that matches the mechanical centre of the package, allowing for a slim camera design. This makes them particularly suitable for miniature OEM barcode engine designs, mobile terminals and sleds, IoT, contactless authentication systems, wearable devices, drones and robotics.

Products

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Infrared imaging

Shortwave infrared filters

Chroma Technology has released SWIR filters for machine vision and remote sensing. The filters can improve food safety inspection, machine vision systems, remote sensing for asset management and a host of other applications.

The SWIR sputter-coated optical filters for remote sensing applications are designed to optimise signal-to-noise ratio. These filters have precise centre wavelengths, narrow transmission bands, exceptional flat-top transmission and OD4 off-band blocking.

The latest additions to the ContrastMax line of optical filters are engineered for automated vision applications, such as machine vision and robot guidance from the visible to SWIR. Chroma's ContrastMax filters cover a range of centre wavelengths, from 380 to 2,800nm, and offer excellent levels of contrast while blocking unwanted light.

Chroma Technology's optical filters are durable and accept wide angles of incidence without chromatic aberrations. With no lamination or thin film degradation, the filters withstand large shifts in temperature and humidity.

www.chroma.com

Extended-SWIR camera

Princeton Infrared Technologies has introduced the 1280BPCam, an extended-SWIR response camera developed specifically for laser beam profiling. The new InGaAs/GaAsSb type-II super lattice (T2SL) detector features 1,280 x 1,024 pixels on a 12µm array pitch. It delivers 90fps at full resolution.

The extended wavelength response of the T2SL material, plus the three-stage thermoelectric cooler, give high sensitivity from 400nm to 2,050nm. The imagers are fabricated on 100mm substrates for low-cost production.

The 1280BPCam's focal plane array integrated in the camera generates full 14-bit pixel data at high resolution, which is transferred by a Medium Camera Link interface. Other features include snapshot exposure, selectable trigger modes and user-selectable regions of interest.

Integration times range from 50µs to greater than 16ms. With less than 275e^- read noise, dynamic range of greater than 1,000:1, plus greater than 20 per cent quantum efficiency for 1.9µm, the camera is ideal for use in a variety of industrial, medical and defence applications.

www.princetonirtech.com

Atlas SWIR IP67-rated models

Lucid Vision Labs has launched the Atlas SWIR IP67-rated GigE PoE+ cameras. The models are based on the Sony SenSWIR 1.3 megapixel IMX990 and 0.3 megapixel IMX991 InGaAs sensors, capable of capturing images across both visible and SWIR light spectrums, and boasting a pixel size of 5µm.

Imaging in the shortwave infrared spectrum opens up many industrial applications, giving greater precision in fruit inspection and sorting, as well as tasks in packaging, infrared microscopy, semiconductor inspection, material sorting and more.

The Atlas SWIR camera is equipped with integrated, single-stage thermoelectric sensor cooling for superior image quality and extended operating temperature range. It measures 60 x 60mm and features active sensor alignment for excellent optical performance, M12 Ethernet and M8 general purpose I/O connectors, industrial EMC immunity, and a wide ambient temperature range of -20°C to 50°C.

The Atlas is GigE Vision and GenICam compliant, supported by Lucid's own Arena software development kit.

www.thinklucid.com

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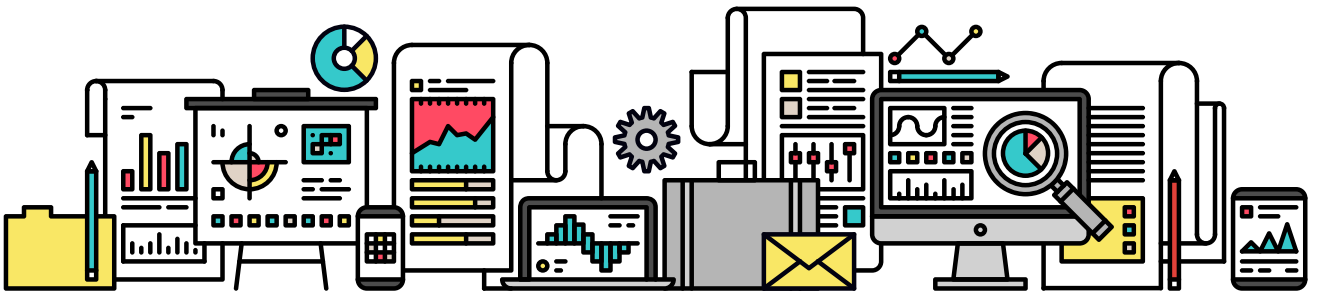

Event-based vision compared with machine vision

IMAGO TECHNOLOGIES

From high-speed applications to tracking, vibration analysis and counting applications: event-based vision opens up new possibilities in numerous machine vision fields

Photometric stereo technique - 3D machine vision's next frontier

SMART VISION LIGHTS

Photometric stereo uses 3D surface orientation and its effect on reflected light to produce a contrast image accentuating local 3D surface variations, making complex inspections cheaper and more effective

High-speed imaging: The benefits of 10, 25, 50, and 100GigE Vision

EMERGENT VISION TECHNOLOGIES

The white paper presents a brief timeline of GigE Vision cameras; advantages of the interface; and information on using 10GigE up to 100GigE to stay on the leading edge of machine vision solutions in manufacturing and beyond

Deep learning: Its proper role and use in machine vision

MATROX IMAGING

Deep learning is a key enabler of Industry 4.0 in the manufacturing sector where machine vision is an important contributor. This white paper from Matrox Imaging details how and where machine vision benefits from deep learning technology, and how to get the best out of deep learning for machine vision.

Advantages of imaging lens ruggedisation

EDMUND OPTICS

Ruggedised lenses address some of the challenges faced in environments with high levels of vibration, shock, and moisture. Edmund Optics explores the features and advantages of different types of ruggedisation in imaging lenses.

Improve production yields with hybrid AI

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Hybrid AI helps designers and integrators balance the best solution and integration with existing infrastructure as they navigate through Industry 4.0, Internet of Things, and artificial intelligence.

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Infrared imaging

Ceres T and Dione S LWIR cameras

New from Xenics are SXGA-resolution (1,280 x 1,024 pixels) versions of the Ceres T and Dione S longwave infrared cameras.

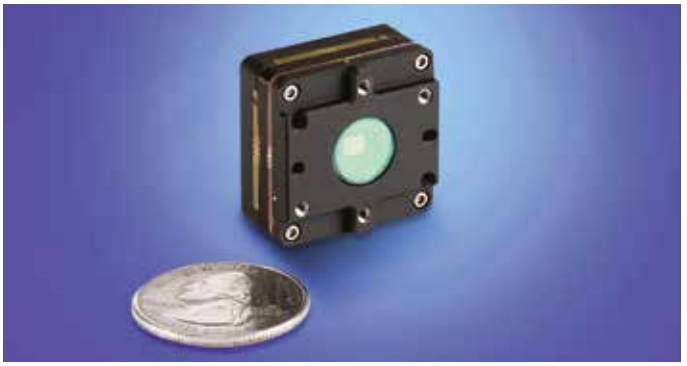
Ceres T 1280 has automatic compensation of internal temperature drift, including within the optical path. This makes it very simple to use, avoiding any additional long and complex calibration.

Moreover, thermographic capabilities are embedded on-board, with the ability to store two calibration packs. Designed for industrial uses, Ceres T 1280 interface is either GigE with PoE or Camera Link, and is GenICam-compliant.

Ceres T 1280 measures 64.5 x 67.6 x 83.5mm and weighs 583g without the lens. It is supplied with Xenics' Xeneth GUI and GenICam SDK and, depending on the application, is offered with 12° HFOV, 16° HFOV, 25° HFOV or 48° HFOV.

Dione S 1280 is supplied with a Samtec ST5 connector that supports the 16-bit digital output (compatible with the Camera Link protocol); the command and control, including triggering capabilities; and the power supply. It comes with either M34 or M45 optical interfaces.

www.xenics.com



Phoenix SWIR models

Attollo Engineering has released QVGA and HD versions of its Phoenix shortwave infrared cameras, with a spectral response from 1.0 to 1.65µm.

The Phoenix quarter-VGA InGaAs camera (320 x 256-pixel resolution) is for cost-sensitive systems, with a price of $4,900 for the camera core with parallel output.

Both QVGA and HD versions weigh 23g without lens, and are designed with size, weight and power requirements in mind. The InGaAs sensors have a 5µm pixel pitch.

The uncooled, HD model has imaging modes that include global shuttering, integrate-while-read, and integrate-then-read. The on-board processing on the HD camera offers sharpening, user-defined convolution filters, region of interest, automatic gain control, and automatic exposure control. Video output for the HD version is parallel CMOS and, optionally, Camera Link, Mipi and USB3.

www.attolloengineering.com

Processing

Gold GPU computers

The new Cincoze Gold series is a range of GPU computers designed to meet the needs of large-scale image processing, machine vision and machine learning applications.

The series includes the GP-3000, a GPU with 720W total system power. It uses a ninth/eighth-generation Intel Xeon/Core CPU with up to eight cores, has a built-in Intel C246 chipset, and supports two sets of DDR4-2666 ECC/non-ECC SO-DIMM up to 64GB.

GP-3000 uses a GPU card expansion box that supports single or dual-card formats: either a single GPU card of up to 350W, suitable for the latest Nvidia RTX 3090; or, in dual-card format, GPU card support is 250W per card.

The GP-3000 series can perform large-scale image processing and complex calculations in real-time. Successful cases cover applications such as automated fault detection on railway tracks and autonomous farming machines.

The GM-1000 series measures 260 x 200 x 85mm, is equipped with an Intel Xeon/Core processor with up to eight cores, and supports 64GB dual-channel DDR4 2,666 MHz SO-DIMM. The combination of computing performance and compact size is ideal for space-limited applications.

The GM-1000 series has an embedded MXM 3.1-type A/B GPU slot, compatible with Nvidia Quadro MXM GPU cards. The overall system power consumption handles up to 360W, and the series is resistant to shocks and vibrations.

www.cincoze.com

GoMax NX vision accelerator

LMI Technologies has released the GoMax NX smart vision accelerator. GoMax NX is a compact, fanless, embedded device that accelerates any Gocator sensor or multi-sensor network in inspection tasks that require increased data processing power.

The accelerator is equipped with an Nvidia Jetson Xavier GPU and can be run through a web browser. GoMax NX enhances data processing power in real-time, minimises cycle times and augments overall inspection performance.

Suitable applications for acceleration include: multi-sensor ring scanning, with Gocator laser line profilers in a ring layout scanning composite flooring; automotive weld inspection, using a Gocator snapshot sensor mounted on a robot to inspect various points around the frame of the vehicle; and to make volume measurements and quality inspection of electric vehicle battery protective foam with Gocator snapshot sensors.

www.lmi3d.com

Cameras

Shr661 127-megapixel camera

The new Shr661 CMOS camera from SVS-Vistek incorporates a Sony IMX661 Pregius global shutter sensor with a resolution of 127 megapixels. The sensor contains 13,392 x 9,528 pixels, with a pixel pitch of 3.45µm.

The camera can operate over a wide temperature range, thanks to SVS-Vistek's SHR cooling system and thermal management. The camera has a Coaxpress 12 or 10GigE interface, with frame rates reaching 17fps and 6.3fps respectively. In addition, the camera has several high-end features, such as customisable flat field and defect pixel corrections.

An I/O framework with multiple inputs and four power-out outputs is provided, supporting precise triggering, as well as sequencers and logical operators. The outputs with the built-in strobe controller can directly drive LED lighting. The GenICam interface with GenTL allows easy integration into all major machine vision software packages. The camera is currently available from SVS-Vistek as a demonstrator.
www.svs-vistek.com

Eagle cooled CCD camera

Raptor has enhanced its range of cooled CCD cameras with the launch of the Eagle 1-megapixel model. Using a back-illuminated CCD – 1,056 x 1,027 pixels with 13 x 13µm pixel pitch – the camera is air-cooled to -80°C to minimise dark current for longer exposures. Using low noise electronics, it offers 2.3e$^-$ readout noise. It is available in C-Mount with an integrated shutter and is the smallest camera in its class at 140 x 126 x 120mm.
www.raptorphotonics.com

IP Ethernet autofocus-zoom block camera

Active Silicon has added IP network capability to its Harrier autofocus-zoom block camera and interface board range.

Applications range from networked surveillance to connected industrial inspection. For example, the Harrier 10x AF-zoom IP camera with Tamron MP1010M-VC offers a lightweight and compact 1,080p solution ideal for remote monitoring, traffic and transport, robotics and ROVs.

The IP Ethernet video stream is transmitted through the Harrier IP camera interface board. With the help of an SoC processor, the board converts the LVDS output of the Harrier camera to a low latency H.264 IP video stream over RTP. The board is compatible with all LVDS output cameras, extending IP video output to all of the Harrier range of cameras, which includes models with global shutter and up to 40x zoom.

Software examples are provided with the free Harrier IP SDK. VISCA commands can also be sent to the camera via the ONVIF server to control camera features.

The interface board can be purchased as board-only, or as part of a pre-assembled complete camera solution; board versions with power over Ethernet and wireless IP interface options are also available.
www.activesilicon.com

Polarised Blackfly S GigE model

Teledyne Flir has introduced the latest addition to its polarised Blackfly S GigE camera lineup – the BFS-PGE-123S6P-C. The 12-megapixel model is well suited for applications dealing with reflective and challenging lighting conditions. It is ideal for use cases like traffic systems, unmanned aerial systems, inspection lines with transparent or reflective parts, and other uncontrolled lighting environments.

The camera pairs the Sony IMX253 MZR sensor with a glare reduction feature built into Teledyne Flir's Spinnaker SDK, making application development and deployment fast and easy. These new GigE cameras with power over Ethernet also take advantage of Teledyne Flir's lossless compression feature, delivering up to 14 fps at full resolution. The camera measures 29 x 29 x 30mm and weighs 36g.
www.flir.com

Visionary-T 3D snapshot sensor

Sick has released a miniature version of its Visionary-T 3D snapshot vision sensor. The Visionary-T Mini is a time-of-flight snapshot sensor that captures both 3D depth and 2D intensity values of every pixel at 512 x 424-pixel resolution. It operates at up to 30 3D frames per second, and has a field of view of 70° x 60°.

The camera is ideal for factory automation, materials handling and logistics environments. Suitable applications include: robot palletising and depalletising; 3D dimensioning, such as packaging completeness checks, warehouse storage and retrieval systems, or for intelligent loading of freight trucks; and as part of navigation systems in automated guided carts, forklifts and mobile robots.

The Visionary-T Mini measures 80 x 70 x 77mm and weighs 520g, so it can fit into small machine spaces, on robot arms, or onto small and lightweight automated guided carts.

It is a rugged industrial sensor with IP65/IP67 housing and no moving parts, capable of operating at temperatures between -10°C and +50°C, and in bright sunlight up to 50kLux. Communication is over industrial Gigabit Ethernet.
www.sick.co.uk

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Tel: +44 (0)1904 788600
sales@edmundoptics.eu
www.edmundoptics.eu

Emergent Vision Technologies
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sales@emergentvisiontec.com
https://emergentvisiontec.com

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Tel: +86-0571-88967998
hikrobot@hikrobotics.com
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JAI A/S
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Kowa
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lens@kowaoptimed.com
www.kowa-lenses.com

LMI Technologies Inc.
Tel: +1 604 636 1011
contact@lmi3d.com
www.lmi3d.com

LUCID Vision Labs GmbH
Tel: +49 (0) 7062 97676 12
sales.emea@thinklucid.com
www.thinklucid.com

Macnica ATD Europe
Tel : + 33 (0) 1 30 15 69 70
sales@atdelectronique com
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MATRIX VISION GmbH
Tel: +49 7191 94320
sales@matrix-vision.com
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Midwest Optical Systems
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Sill Optics GmbH & Co. KG
Tel: +49 9129 9023 0
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Tel: +49 (8152) 99 85 0
info@svs-vistek.com
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TPL Vision
Tel: +44 (0)1738 310 392
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Event-based vision

Join us as we investigate neuromorphic sensing, otherwise known as event-based imaging. Event-based image sensors record changes in a scene – events – rather than capturing everything frame by frame.

Speakers

Josh Gibson
Senior physicist at Cambridge Consultants

Josh will present a device the firm has developed that automates sterility testing of cell therapy treatment using Prophesee's event-based sensor. The PureSentry device is able to detect contamination in cell therapy batches in real time, compared to having to run a sterility test requiring a 7 to 14 day incubation period.

Luca Verre
CEO of Prophesee

Luca will give an update on Prophesee's event-based sensors and where the technology is best used.

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