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On-chip spectral imaging and sensing transition towards marketable technologies

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The shift from lab research to real-world production of scientific innovations comes with challenges. For spectral imaging chips, we address practical application needs by identifying real problems, solving them efficiently and delivering functional solutions. This has enabled a substantial transition from academic research to market-ready products.

Over 80% of human information is acquired through vision. Traditional imaging chips, which mimic the human eye, capture only three colour channels (RGB) and lack the ability to detect high-dimensional spectral information. Spectral data, often referred to as the 'fingerprint of materials,' holds immense potential for advancing our understanding of the universe, decoding biological information and exploring new materials. However, current spectral imaging technology is based on seventeenth-century Newtonian prism principles and mechanical scanning, resulting in large, expensive and slow cameras, limiting its everyday applications.

Using computational imaging principles, we have developed, to our knowledge, the world's first real-time ultraspectral imaging chip[1]. This chip decodes high-dimensional spectral information by using metasurfaces to encode light and a complementary metal–oxide–semiconductor (CMOS) image sensor (CIS) to map the spectral data into the electrical domain. With a spectral resolution of 0.5 nm, more than 600 spectral channels and imaging times as fast as tens of milliseconds[2], it allows for the capture of spectral data from every point in an image in a single snapshot. The technology has been recognized for its contributions to the field[3] and since our first laboratory prototype in 2018, we have filed over 100 patents worldwide. Additionally, we have established Seetrum, a technology transfer company that originated from Tsinghua University.

In transitioning from the lab to commercial production, we have consistently focused on addressing real-world application needs by identifying genuine challenges, solving them and ensuring practical outcomes. Unlike the incremental evolution of traditional technologies, the leap from cutting-edge scientific breakthroughs to market-ready products presents unique challenges. Years of exploration by our team have bridged this gap and we outline the key insights gained from this process below.

The nature of the technology

Successful technology transfer rests on two fundamental pillars: the intrinsic value of the technology and its ability to meet existing needs while creating new ones, and its advantage and feasibility in application.

The spectral imaging chip offers a disruptive advancement in next-generation imaging. It exceeds human visual capabilities, making it a versatile sensing tool for fields such as artificial intelligence (AI), machine vision, autonomous driving, medical devices, augmented reality and smart cities. Moreover, as a key dimension of information for research in areas such as astronomy, medicine and life sciences, on-chip spectral imaging holds great promise for groundbreaking discoveries.

In terms of its advantages and feasibility, the chip works by modulating light in the spectral domain through metasurfaces, mapping this information onto a image sensor and reconstructing the spectral data via algorithms or neural networks. The principle of the chip enables: (1) high flexibility in metasurface design for precise spectral modulation[4,5], (2) compact pixel size for high spatial resolution, (3) seamless integration with CIS across applications ranging from microscopy to smartphones to telescopes and (4) cost-effective mass production using standard CMOS processes. These features offer high precision, miniaturization and scalability, making the technology highly feasible for mass-market applications.

The industrialization team

A competent industrialization team is essential for the successful implementation of cutting-edge technology. The development of the spectral imaging chip required breakthroughs in physical mechanisms, fabrication processes and AI algorithms, all of which presented considerable technical challenges. Relying on existing companies for technology transfer proved impractical, highlighting the need for a specialized team.

Our core team, made up of exceptional graduates from our lab, brings several key advantages. They possess deep expertise in the technology, enabling better insights into its practical applications, and their passion for the project ensures their commitment to overcoming obstacles. Additionally, the equity structure of the company is designed to motivate team members and support long-term growth.

Integration with the industry supply chain

Successful commercialization also requires integrating into an established industrial supply chain. We prioritized forming strategic partnerships with key players from both the upstream and downstream sectors. During early-stage financing, we secured investments from Will-semi, the world's third-largest CIS manufacturer, and Hikvision, the world's largest security camera vendor. Their support has been instrumental in the successful commercialization of our spectral imaging chip.

Business strategy: technology commercialization and market selection

Technology-driven companies face substantial challenges in business development, especially when aligning new technologies with commercial products. Every stage of this process – from technology-product fit to product-market fit – requires careful evaluation.

In the first stage, Seetrum leveraged our computational spectral technology platform to expand spectral modulation hardware, including metasurfaces, colour filters and gratings. This allows us to offer diverse on-chip spectral sensors, AI algorithms and intelligent sensing solutions to customers worldwide.

At the product-market fit stage, aligning the technology with market demand is essential. We have focused on high-potential markets such as smartphones, machine vision and medical imaging, ensuring our technology can support the sizeable R&D investments needed for advanced optoelectronic chip technologies. As these markets mature, we aim to expand into additional segments, with the goal of making spectral sensing ubiquitous.

Future directions

Spectral imaging chip technology is rapidly evolving, with ongoing developments in spectral encoding, multidimensional light field computation and AI-driven reconstruction algorithms. Future advancements may include extending spectral bands into the infrared and ultraviolet ranges and exploring interdisciplinary applications. A promising direction for this technology is the development of 'in-sensor computing chips'[6] that are tailored for complex visual tasks. In the AI era, these chips could become fundamental modules for AI systems, enabling devices such as smartphones, robots and drones to perform advanced spectral sensing and computing tasks. With CIS as the most integrated optoelectronic detector array available, every pixel in a high-resolution camera could both sense and compute, opening the door to a new era of neural network chips with matter meta-imaging.

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Competing interests

K.C. and Y.H. are co-founders of Seetrum and hold shares in the startup.