Enhance imaging precision with advanced optical filters for life sciences and medical imaging

A White Paper on behalf of Chroma Technology, in conjunction with Electro Optics

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Introduction

Medical and scientific imaging are undergoing a transformation, driven by increasing demands for precision, speed, and integration across diagnostic and research systems. Imaging modalities such as fluorescence microscopy and Optical Coherence Tomography (OCT) are reaching new frontiers, but optical filters can be seen as a critical bottleneck or an underutilised opportunity in many institutions.

However, there is still substantial potential for innovation led by evolving design of filters, customisable and off-the-shelf alike. While manufacturers and application developers must continue to take heed of stringent regulations and funding requirements in medical and life science spaces, there is still room for growth with limited resources. By partnering with a supplier of optical filters with the contextual expertise to match specific end goals, clinicians and researchers in these fields can overcome technical complexities to better serve patients and customers.

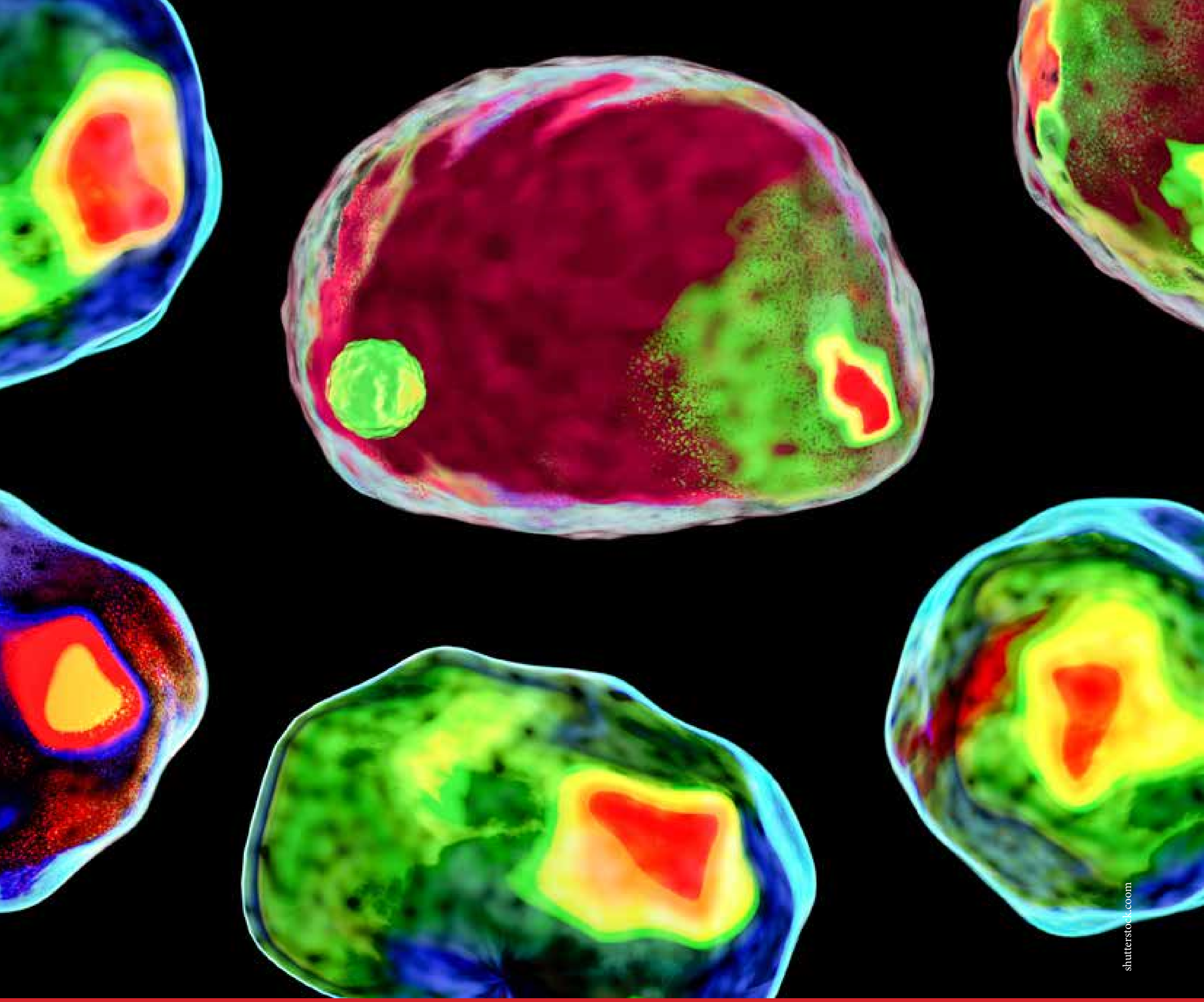
This White Paper will provide practical insights for imaging system manufacturers, hospitals, and research institutions. Insights will be presented around emerging filter technologies, system compatibility challenges, and real-world examples where filter innovation has directly improved patient diagnostics and research efficiency.

Executive summary

The next wave of innovation in life sciences and medical imaging, from advanced fluorescence microscopy to Artificial Intelligence (AI)-driven diagnostics, hinges on the performance and reliability of optical filters. While new modalities demand increasing precision, filter selection and integration remain an underutilised opportunity that can dictate system complexity, adoption speed, and data quality.

This paper synthesises insights from industry experts regarding the critical challenges in the sector: balancing advanced system complexity with user-friendly operation, integrating high-performance custom filters with regulatory explainability, and ensuring data fidelity for AI training.

Chroma Technology offers the specialised optical expertise and collaborative model required to navigate these complexities. By engaging early in the design cycle, system manufacturers and research institutions can move beyond generic components to implement optimised, application-specific filtering solutions – whether custom or off-the-shelf – to accelerate discovery, ensure patient safety, and gain a competitive advantage in a rapidly evolving market.



MEDICAL AND LIFE SCIENCE IMAGING BARRIERS

The main challenge is balancing advanced system complexity with ease of use and clinical adoption. Researchers and clinicians working in healthcare premises, universities and laboratories often lack depth of technical expertise around the imaging equipment they are using. Therefore, there needs to be a common ground between those end users and suppliers, when finding the right systems for specific requirements.

Martin Brill, Applications Specialist at Rapp OptoElectronic, highlighted that modern imaging systems follow the advancement of technology and science, and therefore become highly complex. This, in turn, leads to a requirement for complex systems and cutting-edge technology from funding agencies supporting innovations – yet this complexity tends to overwhelm many users, especially students, limiting practical utility. "Systems must integrate advanced fluorescence microscopy components, such as filters and light sources, without becoming too complicated," he said. "The rapid advancement in imaging resolution, speed, and new fluorophores demands sophisticated system design. This complexity creates a steep learning curve that slows adoption in research and clinical settings. The tension is between offering broad functionality and user-friendly operation, especially for non-expert operators."

Aravind Venugopalan, Co-Founder and CTO of Singular Photonics, added that emerging technologies, such as Single Photon Avalanche Diodes (SPADs), face adoption hurdles due to the need for extensive user training and configuration expertise. He said: "Users expect performance improvements, which places pressure on engineering robust, plug-and-play systems. The challenge is in delivering cutting-edge technology that fits seamlessly into existing workflows. This adoption lag is typical of novel sensor technologies bridging research and clinical use."

Georg Draude, General Manager at Chroma Technology, noted a shift away from super-resolution microscopy hype towards broader tissue-level imaging approaches, such as proteomics and multi-omics, which better address clinical needs. He said that "startups focus on imaging larger tissue sections, of around 200 to 400 microns, to detect disease markers more effectively. This trend indicates a market demand for practical diagnostic capabilities over incremental resolution improvements."

Inefficiencies remarked elsewhere during discussions elsewhere pointed towards siloed data delaying diagnostics and patient care; and low flexibility and speed to market due to stringent regulations and high risks of misdiagnosis.

FILTER TECHNOLOGY AND CUSTOM SOLUTIONS

Custom and complex filter designs are evolving but face challenges in communication, manufacturing, and regulatory acceptance. While customisation can be challenging in frequent cases of low technical knowledge on the part of end users that only see the front end of imaging systems, there are certain scenarios where off-the-shelf filters can work best.

Thomas Albrow-Owen, Co-Founder and CTO of Prospectral, said that “advanced metasurface filters enable highly customised spectral sensing beyond traditional bandpass filters, optimising chemical detection or computer vision processing. These filters can reduce system complexity by targeting needed spectral bands instead of capturing full hyperspectral data.”

Metasurface filters can be manufactured on sensor pixels, enabling ultra-compact imaging. Applications include chip-on-tip endoscopes and specialised fluorescence multiplexing.

Oliver Lischtschenko, CEO of Coher Sense UG, added that mathematically complex filter shapes, while outperforming traditional bandpass filters, are harder to understand and explain, which can complicate regulatory approval. “AI-driven design algorithms create unexpected filter profiles, offering superior image quality. There is a trade-off between optimising performance and maintaining explainability. Wider knowledge sharing and education are needed to bridge this gap.”

Martin Brill noted that many users still rely on traditional bandpass filters for practical applications, such as multi-colour fluorescence imaging and UV microscopy or fluorescence microscopy with added temperature jump experiments, highlighting ongoing demand for conventional solutions. These applications therefore create dedicated adaptation demands for filter producers. “Complex filters are often reserved for research-grade fluorescence microscopy,” he said. “Customers prefer filters that enable straightforward data interpretation without advanced computational tools. The spectral range of interest spans deep UV to mid-NIR.”

According to Jez Graham, Founder and Managing Director at Custom Scopes Limited, angle-of-incidence effects are critical when integrating filters into microscopes; and compact designs don’t always allow for using filters in infinity space, requiring careful optical design consideration. “Filter design must accommodate the specific optics of the imaging system,” he said. “Metalenses offer potential to combine filtering and focusing optics in compact systems. These advances enable miniaturised, highly manufacturable imaging devices. Optical design complexity is increasing but brings new capabilities.”

LEGACY SYSTEM INTEGRATION AND COLLABORATION

Due to the high risk of breaching healthcare regulations and negatively impacting medical diagnoses and procedures, legacy imaging systems remain widespread. Upgrading legacy imaging systems with modern filters is generally feasible, but requires early collaboration to avoid costly missteps.

Jez Graham reported that improved filters can enhance legacy instrument performance and enable new fluorophore detection, with limited resistance if changes preserve data consistency. This can aid an array of medical application areas including diagnostic imaging and molecular tracking. While generally, retrofitting extends instrument life and opens new applications, "users may resist if new filters disrupt historical data comparability", according to Graham. To aid the transition, though, filter providers can supply aftermarket solutions matching legacy filter sizes.

Georg Draude stressed the importance of early engagement with filter companies during product development, stating that "late filter involvement leads to engineering challenges and delays. Educating customers on benefits of early filter collaboration can save money and improve outcomes. This also enables better optimisation of overall system performance."

Csilla Timár-Fülep, Optical Engineer at Ansys, now part of Synopsys, added that "simulation and virtual prototyping are becoming pivotal in filter system design. They enhance communication by providing numerical data and visual scenarios understandable to both engineers and biologists, accelerating agreement and design validation. This approach shortens iteration cycles and reduces costs, and supports cross-functional collaboration by shared understanding."

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AI, DATA QUALITY, AND IMAGING

Medical and life science institutions are increasingly integrating AI into their data workflows, which is overlapping into next-gen imaging systems. AI's effectiveness in imaging heavily depends on high-quality, well-annotated data enabled by precise filtering.

Csilla Timár-Fülep highlighted the risk that poor quality data can lead to AI misdiagnosis, underscoring the importance of clean, high-fidelity filter output for training. She said: "Filters provide critical data purity for reliable AI inference. Mismanaged data can cause false identifications and diagnostic errors." Additionally, she pointed to maintenance of standardised data with annotations as a key element in full alignment with strict regulations, while using trustworthy AI.

According to Oliver Lischtschenko, "humans are the weak link in annotation and data context", advocating AI assistance to reduce human error in data handling. He added: "Annotation quality directly affects downstream AI model performance. This approach complements advanced filtering for data integrity."

Thomas Albrow-Owen noted a paradigm shift from cameras mimicking human vision to machine vision-specific systems optimised for AI processing, where raw spectral data may never be visualised by humans. He said that "cameras designed for human-like RGB capture are suboptimal for AI. Designing systems for machine learning workflows enables richer, more useful data. This requires new filter and sensor concepts tailored to computational needs. Human oversight remains important but is shifting to verification stages."

Georg Draude remarked on researchers' insistence on retaining raw data for transparency and post hoc analysis despite AI advances, ensuring traceability and trust in biomedical research. "Raw data remains the gold standard for scientific validation," he said. "AI and filtering augment, but do not replace fundamental data capture. This maintains rigorous standards in life science imaging. It affects how filters and imaging systems are designed and validated."

Chroma Technology: partnering for precision and speed
Overcoming the technical and systemic challenges identified in this White Paper requires more than simply specifying a filter; it demands deep collaboration with an optical partner that can act as a systems integrator.

The Chroma advantage is defined by three pillars:

Unmatched design expertise
Chroma's technical team moves beyond simple specifications, helping OEMs and researchers optimise the entire optical stack, from initial concept to final manufacturing. This early engagement eliminates costly late-stage engineering challenges (as noted by Georg Draude) and ensures filter performance is maximised for the system's unique angle of incidence, fluorophore, and sensor configuration.

Breadth of solution
While leading innovation in metasurface filters and complex computational designs, Chroma maintains an extensive catalogue of standard, high-performance bandpass filters demanded for practical, non-expert applications. This ensures that every need, from cutting-edge research to reliable legacy system upgrades, can be met with minimal delay.

Quality and trust for AI
Recognising that "poor quality data leads to AI misdiagnosis", Chroma prioritises manufacturing processes that deliver the exceptionally high-fidelity filter output required for robust machine learning models and regulatory compliance.

FUTURE TRENDS AND MARKET DIRECTIONS

Miniaturisation and integration with AI-driven digital twins are poised to transform imaging and diagnostics accessibility globally. The panel collectively agreed that making devices smaller would unlock new opportunities for innovation, boosting application areas including microscopy and neuroscience.

Oliver Lischtschenko predicted that miniaturisation will drive more affordable and accessible medical imaging into smartphone and tablet augmentations, making diagnostics affordable and widely accessible. Meanwhile, "digital twins will revolutionise instrument design and regulatory validation. The adoption of virtual prototyping would shorten development cycles and reduce physical testing. This could trigger regulatory frameworks to evolve rapidly in response".

Csilla Timár-Fülep emphasised cost effectiveness and portability as critical for healthcare markets, especially in resource-limited countries. "Affordable devices are essential to expand global patient access, and miniaturised, wearable, or portable imaging systems are high priority," she said. "Cost constraints shape filter and system design decisions. This aligns innovation with global health equity goals."

Georg Draude cautioned that miniaturisation risks misdiagnosis if devices are used without expert interpretation, underscoring the ongoing need for skilled professionals. He said that "consumer-grade medical devices may produce false positives/negatives. Medical expertise remains crucial for accurate diagnosis and treatment. Technology must balance accessibility with clinical safety." Despite these risks, research progress in cancer treatment offers hope, according to Draude.

Thomas Albrow-Owen suggested smart glasses represent a near-future platform for miniaturised optical systems, blending consumer and medical applications. "Smart glasses may integrate metasurface optics and spectral filters," he said. "This wearable format aligns with trends in portable diagnostics. Development progress suggests market readiness within two years. This could drive widespread adoption of advanced optical sensing."

Conclusion

The future of medical and life science imaging is defined by miniaturisation, AI integration, and the demand for data quality. In this environment, optical filters are no longer passive components but active enablers of system performance and diagnostic accuracy. Successfully navigating the tension between advanced technology and clinical usability requires strategic expertise.

Organisations seeking to transform imaging workflows need a strong partner. By offering a consultative approach that spans materials science, advanced coating technologies, and regulatory insight, Chroma Technology provides the foundation for innovation – from accelerating the adoption of novel systems to ensuring reliable, high-fidelity data capture for AI.

Targets, and patient and customer needs, can be met by leveraging the right expertise, such as Chroma Technology. Early engagement with a filtering specialist is not just a tactical decision but a strategic partnership that prevents costly missteps, accelerates time-to-market, and secures the highest possible performance from your next-generation system.

Contact sales@chroma.com

Get in touch with a filtering specialist at Chroma Technology today to reach the full potential of your imaging innovation ambitions.

With thanks to all roundtable participants

Aravind Venugopalan, Co-Founder and CTO of Singular Photonics

Csilla Timár-Fülep, Optical Engineer at Ansys, now part of Synopsys

Jeremy (Jez) Graham, Founder and Managing Director of Custom Scopes Limited

Martin Brill, Applications Specialist at Rapp OptoElectronic

Oliver Lischtschenko, CEO of Coher Sense UG

Tom Albrow-Owen, Co-Founder and CTO of Prospectral

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