



## Congratulations to New ICFO PhD Graduate

Dr. Sebastian Hagele graduated with a thesis entitled *Compact Phase Imaging Platform and its Application to Material Science and Manufacturing*

July 23, 2024

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We congratulate Dr. Sebastian Hagele who defended his thesis today in ICFO's Auditorium. Dr. Hagele obtained his MSc in Applied Photonics at Aalen University (DE). He joined the Optoelectronics research group at ICFO led by ICREA Prof. Dr. Valerio Pruneri as a PhD student. His thesis, entitled *Compact Phase Imaging Platform and its Application to Material Science and Manufacturing*, was supervised by ICREA Prof. Dr. Valerio Pruneri and Dr. Roland Alfonso Terb

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### ABSTRACT:

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As the world moves towards increasingly miniaturized and complex technologies and devices, the need for imaging and metrology tools for precise material characterization and

fabrication process control is rising accordingly. For highly transparent and ultra-thin structures and samples (e.g., optical coatings, lithographic structures or biological cells), intensity-based imaging techniques fall short due to insufficient contrast, as well as failing to provide quantitative information.

To overcome these limitations, the field of phase imaging, based on superposition and interference of light, has emerged. In order to create image contrast, phase imaging does not leverage changes in intensity, but rather, as the name implies, changes in the phase of the electro-magnetic wave. With a long-standing history, and Nobel prizes awarded in 1953 to Zernike's  $\frac{1}{2}$  phase contrast microscope  $\frac{1}{2}$  and 1971 to Gabor's holographic methods, the field has evolved to  $\frac{1}{2}$  quantitative phase imaging  $\frac{1}{2}$  (QPI), using sophisticated methods and setups to control and manipulate the state of light in order to recover the phase information quantitatively. Herein, the category of  $\frac{1}{2}$  common-path  $\frac{1}{2}$  techniques promise adaptable, compact, robust, and cost-efficient imaging devices, enabling use in industrial applications outside of a well-controlled lab

environment. In this thesis, we will describe the development and technological innovations of a  $\frac{1}{2}$  common-path  $\frac{1}{2}$  phase imaging platform based on the  $\frac{1}{2}$  lateral-shearing interferometric microscopy  $\frac{1}{2}$  (LIM) technology. We will implement and adapt the platform to various optical setups, e.g., for large-area lens-free imaging and for high-resolution microscopic imaging. We will also demonstrate the performance and versatility of the platform by exploring a range of applications, with a focus given to material science

and manufacturing. Specifically, we will perform volumetric imaging of the tiniest femtosecond laser-written refractive index (RI) changes inside glass. This is followed by the characterization of semi-transparent ultra-thin gold films using multispectral intensity and phase imaging, enabling us to determine the complex RIs of the films of varying thickness. Lastly, we will apply the platform to the imaging of curing grades and RI changes in photopolymers, such as those used in resin-based 3D printing. Further applications of the platform could include surface metrology, imaging of 2D materials, as well as quantitative phase imaging for bio- and cell-imaging applications, with the possibility of integrating the whole platform into a compact add-on which could be added to any commercial microscope. In summary, this thesis will make evident the significant potential of phase imaging in both research and industrial settings, enabled by the proposed compact phase imaging platform. The work builds the foundation for future innovations and development with a potentially lasting impact on the

#### **Thesis Committee:**

Prof. Dr. Sylvania F. Pereira, TU Delft

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