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Submission deadline: 15th April 2027

Scientific discovery and advanced manufacturing fundamentally rely on instruments to extract quantitative physical information from the world. In fields ranging from molecular biology and quantum materials to semiconductor fabrication, laser processing, and ultra-precision metrology, measurement tasks increasingly push against physical trade-offs: photon budget versus acquisition speed, spatial resolution versus field of view, and measurement throughput versus sensitivity. Traditionally, instrument development has largely followed a decoupled paradigm: physical hardware is optimized to form high-fidelity images or analog signals, while downstream software handles reconstruction, filtering, and inspection as separate steps. While computational sensing and model-based reconstruction have long enabled measurements beyond direct imaging, AI now makes it practical to jointly optimize physical encoding and computational inference end-to-end, and to close the loop between measurement, assessment, and adaptation in real time.

Differentiable physical models and end-to-end optimization frameworks allow hardware components—optical masks, illumination patterns, metasurfaces, sensor readouts—to be treated as learnable physical layers, jointly optimized with reconstruction algorithms to maximize measurement accuracy, efficiency, and robustness at the system level under realistic manufacturing tolerances and noise. Advances in efficient inference and real-time control further enable instruments to dynamically steer illumination, exposure, or scanning strategy based on incoming data, to reconstruct physical parameters by leveraging physics-based measurement models, and to assess their own reliability through in-situ self-calibration and uncertainty quantification. Together, these developments are creating conditions for adaptive measurement systems with built-in calibration and reliability assessment that can respond to drifting conditions and complex sample variability.

This special issue of *Light: Advanced Manufacturing* focuses on the deep integration of artificial intelligence with optical instruments, precision metrology, and manufacturing platforms. We seek Articles, Letters, and Review Articles that demonstrate verifiable improvements in measurement capability, reliability, or operational throughput. Topics of interest include, but are not limited to: joint optimization of optical elements and reconstruction algorithms; AI-enabled quantitative optical imaging, spectroscopy, interferometry, and multidimensional sensing; active and event-driven acquisition with adaptive illumination, region-of-interest tracking, and uncertainty-driven re-sampling; self-calibration, drift compensation, out-of-distribution failure detection, and measurement uncertainty quantification; in-line semiconductor metrology and measurement-guided process monitoring and adaptive control in laser processing and precision manufacturing; and cross-device model transfer and autonomous instrument operation. We also welcome investigations into systems that adapt across instruments and operating conditions and that identify when additional measurements or recalibration are needed. Research contributions should identify the role of AI in the measurement pipeline, quantify instrument- or system-level gains against appropriate baselines, and characterize associated costs, prior assumptions, and limitations under relevant operating conditions. Experimental validation on physical instruments is strongly encouraged; methodological and theoretical contributions should establish clear relevance to instrument performance through appropriately validated physical models and realistic operating constraints.

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