Picometre optical topological metrology of nanostructures at a million measurements per second

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It is now well understood from works on the topology of light, that complex optical fields (e.g. superoscillatory fields) can be structured at deeply subwavelength scales. Point-like singularities, zones of energy back-flow and strong variations of phase and intensity can be orders of magnitude smaller than the wavelength. As such, scattering of light on nanoscale objects can strongly depend on exactly where the object is actually located in the structured field. This is the foundational idea of metrology with topologically structured light. Moreover, in localization metrology the use of artificial intelligence in the analysis of scattered light allows for instrumental fluctuations and drifts in the whole sample position to be distinguished from the displacements of the nanoscale object with respect to its immediate environment. Furthermore, we demonstrate that ultrafast cameras allow atomic level metrology with a rate of one million measurements per second which gives access to the studies of dynamical processes such as driven or thermal motion in nanostructures.