Meta-Instrument: An Opto-Mechanical Platform for Imaging Near-Field Optical Instruments

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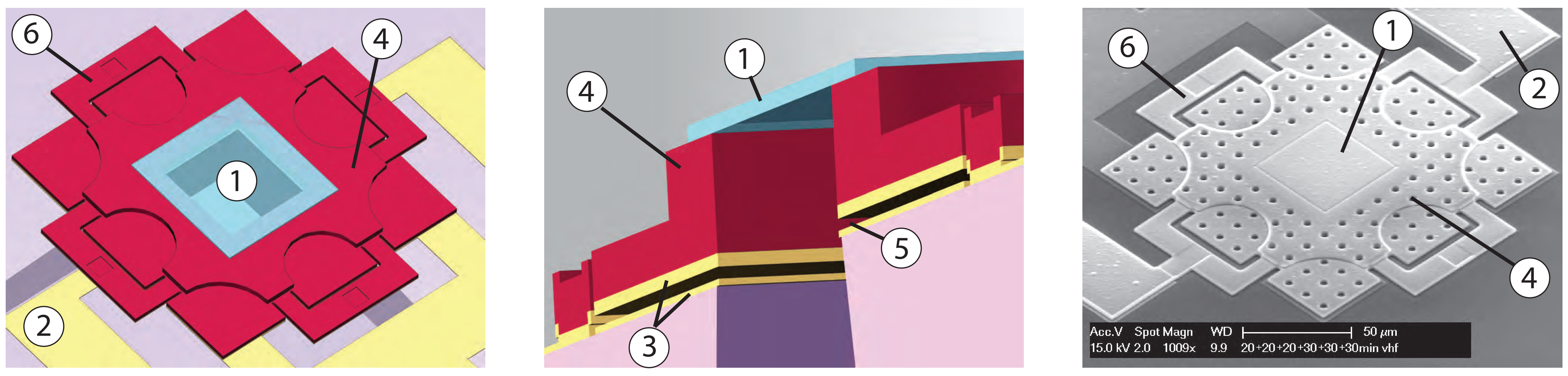
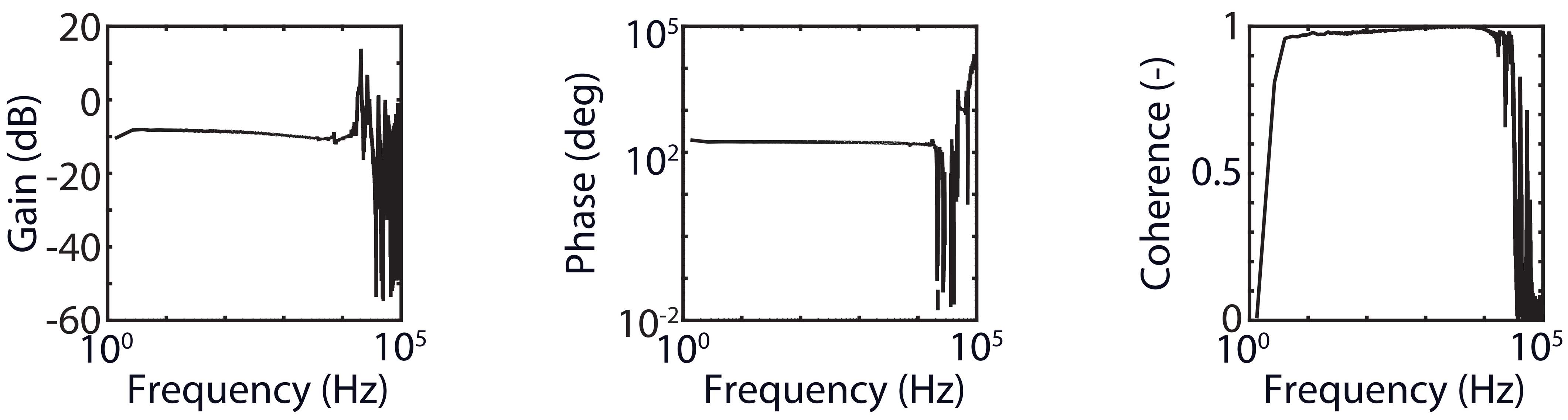
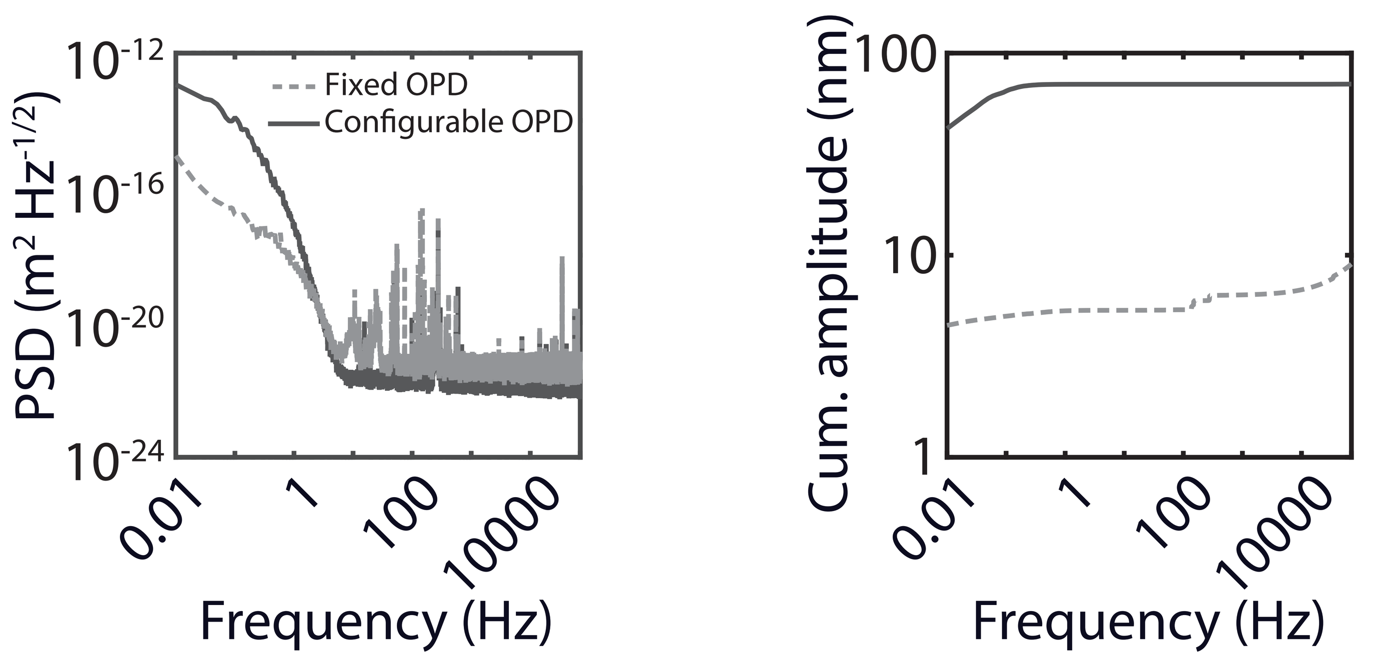
Nanopositioning MEMS device (1) Transparant window, (2) Electronic leads, (3) Electrodes, (4) Moving plate (SiC), (5) Air gap of 500 nm, (6) Leaf springs



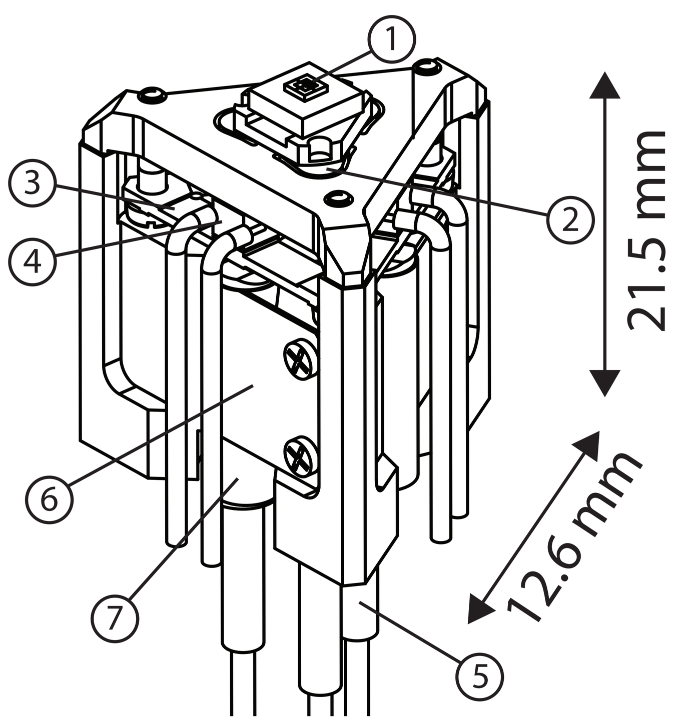
Fine positioning stage The stage and interferometers show a large signal coherence up to 10 kHz. This allows for a high bandwidth tracking of the sample.

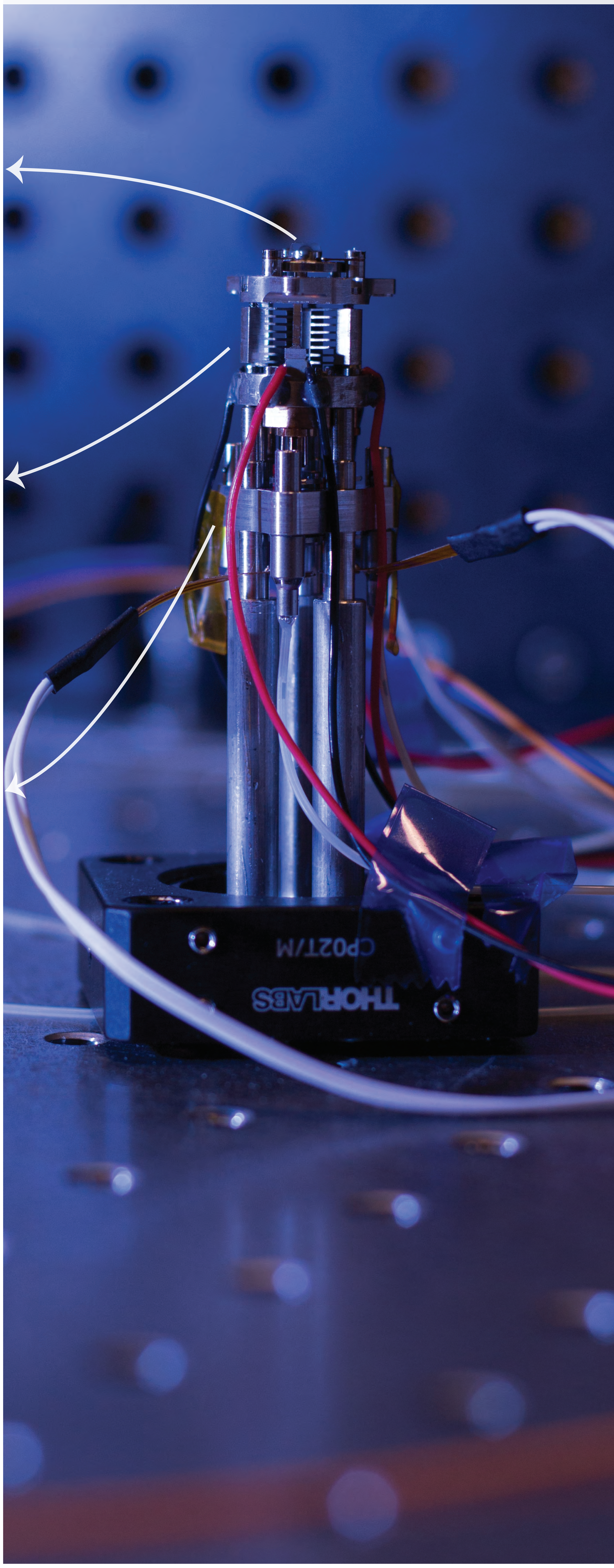


Fiber interferometers as distance sensors
Measure the motion of the finepositioning stage. By stabilizing the temperature of the optical path difference, the noise is reduced from 70 nm r.m.s. to 10 nm r.m.s. over 70 kHz.

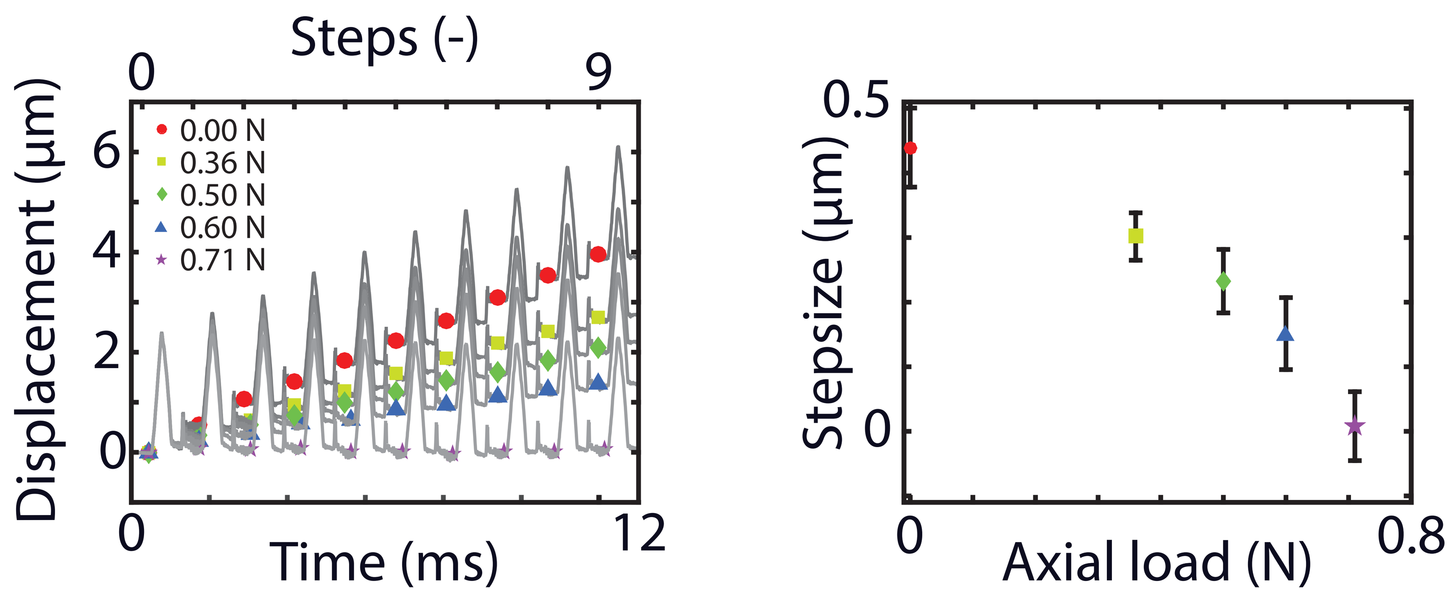


Second generation
(1) MEMS nanopositioning device
(2) Mirror surfaces for interferometers
(3) Leaf spring that preloads piezo element
(4) Piezo element for fine positioning
(5) Fiber interferometer
(6) Leaf spring that clamps the carbon rod
(7) Carbon rod of the coarse positioning





Combined fine and coarse positioning
The new linear actuator can be used for fine positioning and coarse stepping at 0.32 µm/step and velocities up to 3.2 mm/s.



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META-INSTRUMENT: AN OPTO-MECHANICAL PLATFORM FOR IMAGING NEAR-FIELD OPTICAL INSTRUMENTS

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In 1947, Chuck Yeager flew a Bell X-1 to break the long upheld belief of the Mach barrier: no one could fly faster than the speed of sound. Physicist today are working to break another such barrier: the diffraction limit. In 1873, Ernst Abbe postulated that the fundamental limit of optical microscopy was limited by the wavelength and the numerical aperture of the optics to approximately half the wavelength [1]. In the visual spectrum, this equates to a resolution limit of approximately 100 nm.

By tapping into the optical near-field, the region where non-propagating fields can still be detected, the diffraction limit can be broken. For new technologies such as hyperlenses and nano-antennas, theoretical resolutions of 10 nm have been reported [3][4].

Industrial application of these imaging artifacts, however, is limited by the lack of an instrumentation platform that is capable of positioning the artifact in extreme proximity to the sample. For the visual spectrum of light, the optical near-field can be detected at distances from the sample measured in tens of nanometers. The two main challenges that are imposed by this are (1) measuring the distance to the sample [2] and (2) positioning it at the required distance.

The meta-instrument is an opto-mechanical instrumentation platform that is designed to meet the requirements imposed by imaging near-field technologies. These concern the positioning accuracy and speed, distance measurement, high bandwidth actuation, optical read-out and instrument dimensions.

The instrument sports a three stage design of coarse approach stage, fine positioning stage and high speed MEMS stage, which are used for engaging to the sample, following the surface topography and maintaining the optical artifact in focus. A topographical sketch can be found in Fig.1.

Fiber interferometers are utilized to close the control loop of the fine positioning stage and realize sub-nanometer control of distance and micro radian control of tip- and tilt of the optical element with a 470 Hz bandwidth.

This paper reports on the ongoing efforts and advances made in realizing the meta-instrument and open challenges for the next iteration.

ACKNOWLEDGMENTS

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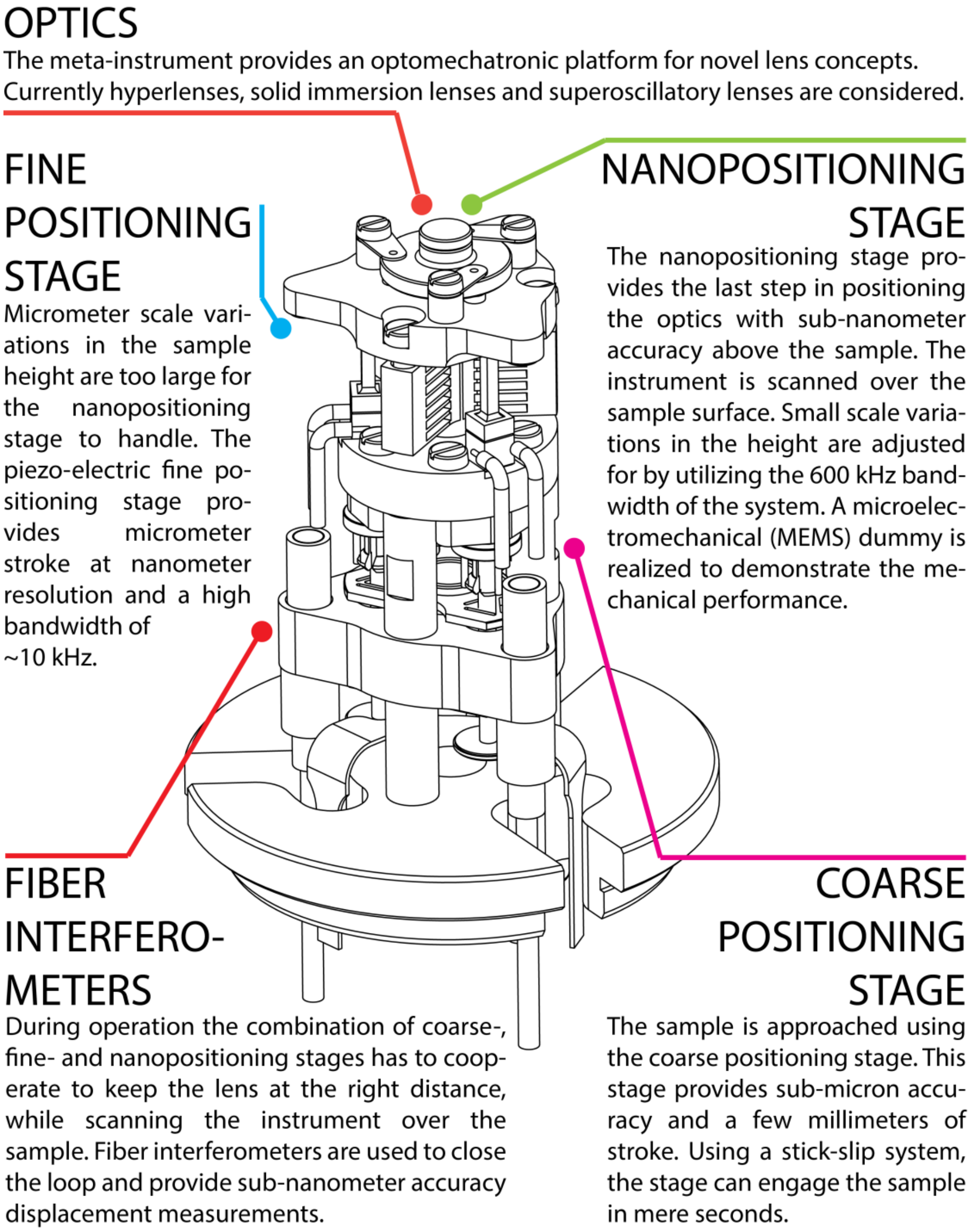

Fig.1: Sketch of the first realization of the meta-instrument.