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Towards contactless scanning thermal microscopy: measuring probe-sample separation

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The heat transfer across (sub)micrometer gaps between two bodies, either through gas conduction or near-field radiative transfer, offers a sensitive means for measuring their separation. In an ideal case, picometer and smaller resolutions are possible [1], and the measurement can be made nearly independent of the material properties at atmospheric pressure. This makes it a promising technique for measuring small separations, for example as a distance sensor in future near-field imaging microscopes [2], or as a stand-alone scanning probe microscopy technique [3].

We have developed a proof-of-principle of such distance sensors. At its core is a bilayer cantilever with an application dependent tip shape at its free end. We are using a microsphere for distance measurements, whereas a sharper tip will provide better lateral resolution for scanning microscopy. When the heat transfer across the gap changes, the resulting change in temperature distribution along the length of the cantilever causes it to deform. This motion is detected using an optical beam deflection system [4]. The full system architecture is laid out in Figure 1a.

This system differs from earlier setups in three ways. First, the temperature of the cantilever is kept constant by changing the output power of the laser diode. The required current is the measurement signal, and can after calibration be translated into absorbed power. This ensures that the temperature difference across the gap is constant and independent of the separation. Second, this makes that the probes do not necessarily need to be calibrated, and that the measurement can be made traceable to the SI system. Lastly, the separation is measured independently at the point of interest, rather than by means of the position actuator calibration. The use of a total internal reflection microscope allows for independent validation of the distances measured with the proposed heat-based distance sensor (Figure 1b).

We present the realized hardware and the measured characteristics of its subsystems (e.g., Figure 1c-e) and show initial distance measurements made with this system.

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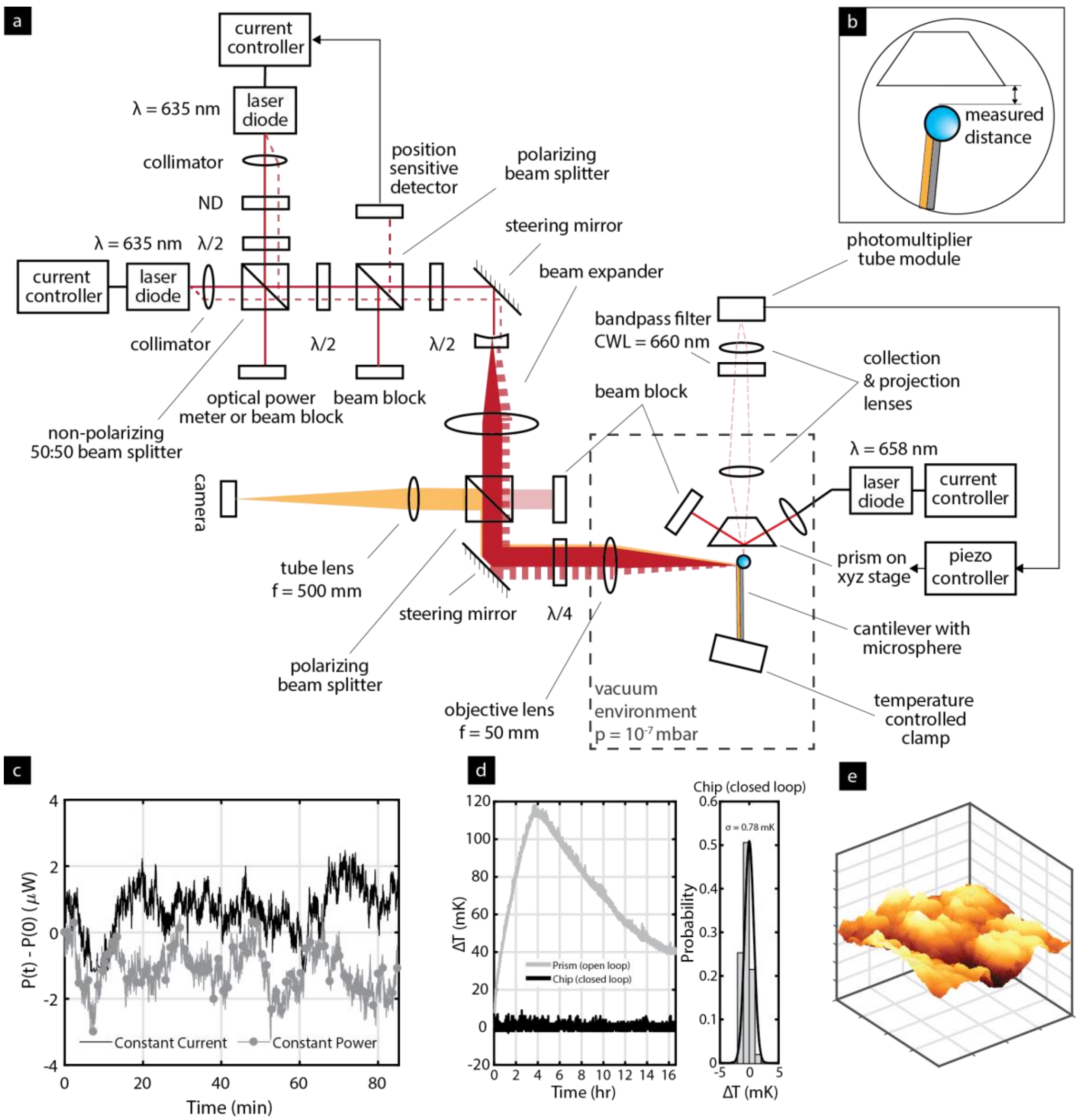

Figure 1 a) System architecture showing the confocal optical beam deflection system (red), imaging microscope (yellow), total internal reflection microscope and thermal control loops. b) Enlarged view of the probe-sample geometry. The distance measured by the TIRM is indicated. c) Measured drift of laser diode output power of $\pm 2\ \mu W$. d) Temperature stability in closed loop of 1 mK over 16 hours. e) topographical view of microsphere surface with a typical surface roughness of 10 nm r.m.s.