Measurement of Picoforces from Light

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A cheap electret microphone together with a lock-in amplifier can measure the pressure effect of light in a simple and sensitive way.

I. Introduction

There are only a few laboratories that are capable of direct light pressure measurement. In Germany, this is done for example by the Physikalisch-Technische Bundesanstalt (PTB):

"First measurements in air yielded a standard deviation of 160 pN for a long-term measurement over 3 hours using a low-pass filter of 0.02 Hz. As initial force measurement at the sensitivity limit of the prototype system, the force was determined which the light pressure of a He-Ne laser exerts with a power of 7 mW. The measured value of 38 pN is only 9 pN smaller than the force calculated from the optical power of the laser and the reflection factor of the disk pendulum." [i]

For absorption the formula $\mathbf{F_a = P / c}$ applies and for reflection $\mathbf{F = 2\ P / c}$. Any light properties (e.g. wavelength) are interestingly not included in the formula.

At P = 7 mW the result is $\mathbf{F = 14\ 10^{-3}\ Ws / 3\ 10^{8}\ m = 47\ pN}$. The PTB measured 38 pN in 3 hours. So indeed 9 pN too little.

The following describes a device that measures in the microwatt range in a few seconds and with a negligible standard deviation. An cheap electret microphone is used as the sensor.

Similar to a rotary voltmeter, the light must pulsate and than detected by a lock-in-amplifier.

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II. Setup

Fig. 1: Experimental Setup

The sensor is an electret microphone with ∅=10 mm and h=10 mm. The ∅=2 mm-sound hole was covered with transparent tape.

The hole was illuminated with a green LED flickering at 11.6 Hz. The power of the LED was specified with resistors.

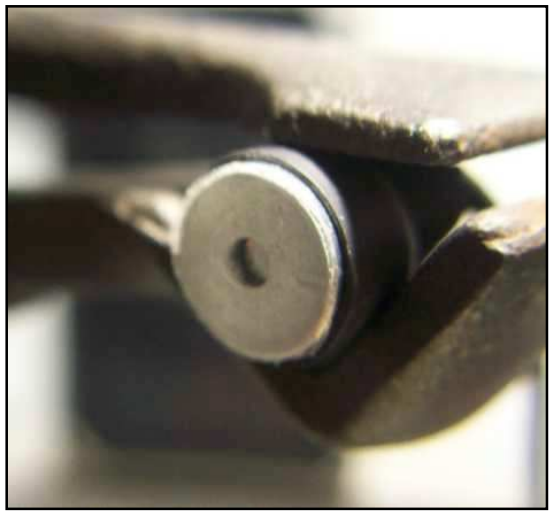

Fig. 2 : Electret microphone

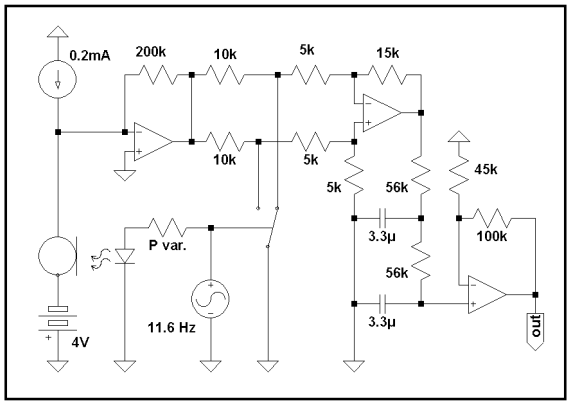

Fig. 3 : lock-in amplifier

The output voltage of the lock-in amplifier of the used Bruker system was measured as a function of the light power.

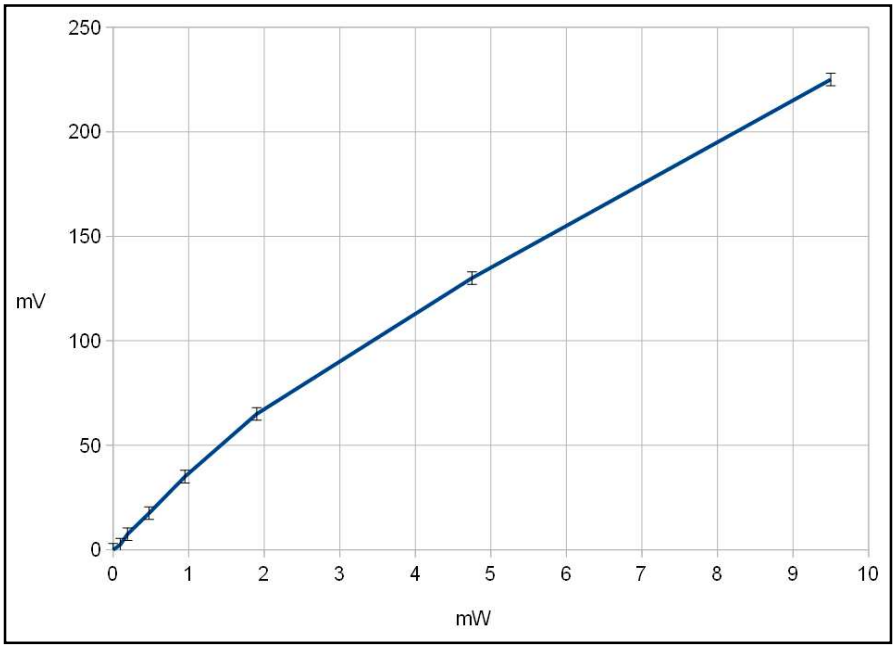

Fig. 4: Lock-in-amp output vs. light power through the sound hole

III. Discussion

This means that a mechanical method is now available as an alternative to electromagnetic sensors such as the eye, photodiodes, photoelements, photoresistors, photocells, photomultipliers and thermal detectors.

Applications as nanogram scales for oscillating masses are also conceivable.

[i] https://www.ptb.de/cms/en/presseaktuelles/journals-magazines/ptb-news/ptb-news-ausgaben/archivederptb-news/news08-3/measuring-nano-and-picoforces.html