Sub-picowatt heat flow measurements & application to measurement of thermal properties of nanostructures

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10th US-Korea Forum
October 15-16, 2013 – Boston, MA

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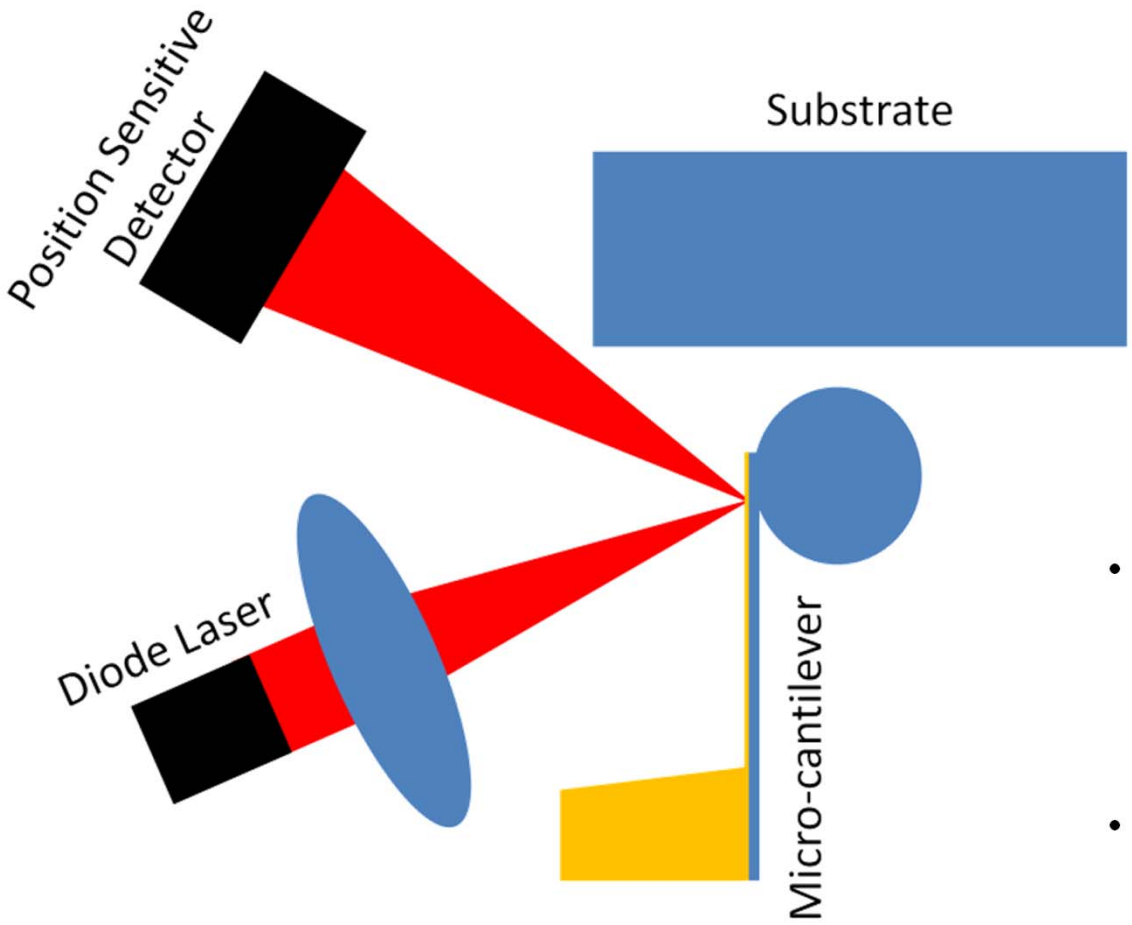
Motivation

“A highly sensitive new type of calorimeter based on the deflection of a ‘bimetallic’ micromechanical sensor as a function of temperature”

Extremely sensitive temperature and power sensor because of its small dimensions and low thermal mass

J. R. Barnes, R. J. Stephenson, C. N. Woodburn, S. J. O'Shea, M. E. Welland, T. Rayment, J. K. Gimzewski, and C. Gerber, Rev. Sci. Instrum., 65 (1994)

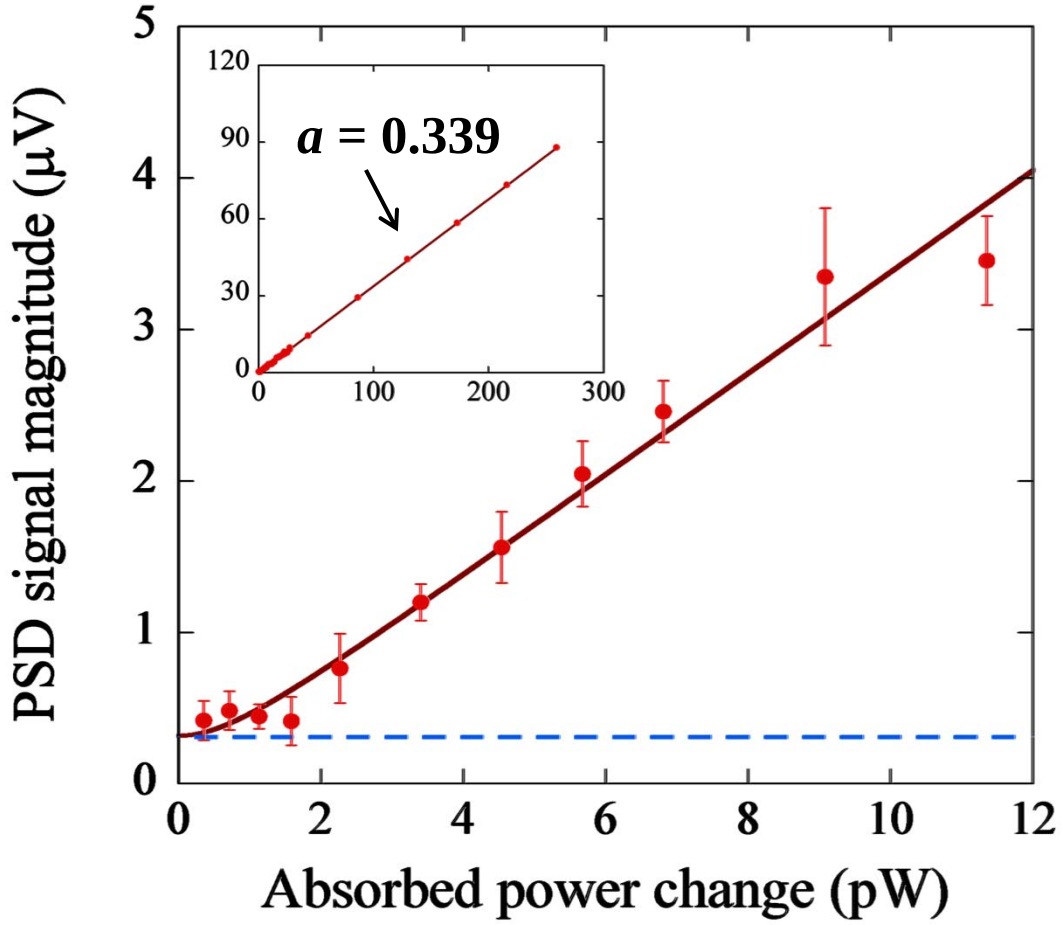
Bi-material cantilevers for thermal sensing



- Bi-material AFM cantilever has been used to measure near-field radiative transfer between a microsphere and a flat substrate*
- Limited by the thermal conductance of the cantilevers

*A. Narayanaswamy, S. Shen, and G. Chen, Phys. Rev. B, 78 (2008)
** A. Narayanaswamy and N. Gu, J. Heat Transf., 133, 4 (2011)

Sub-picowatt sensitivity



Curve fit of the form:

$$y = a\sqrt{x^2 + x_n^2}$$

where x_n is the noise equivalent power

For 1.2 mHz BW:

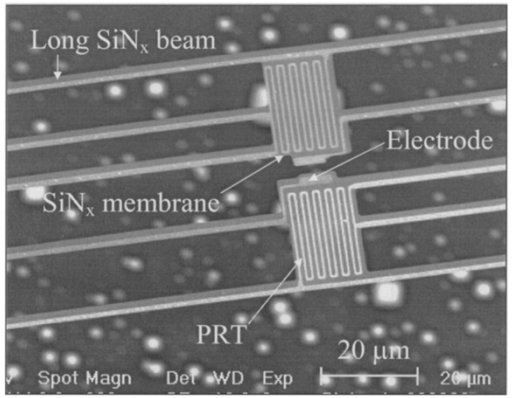
$a = 0.336 \pm 0.004$ μV/pW

$x_n = 0.9 \pm 0.2$ pW

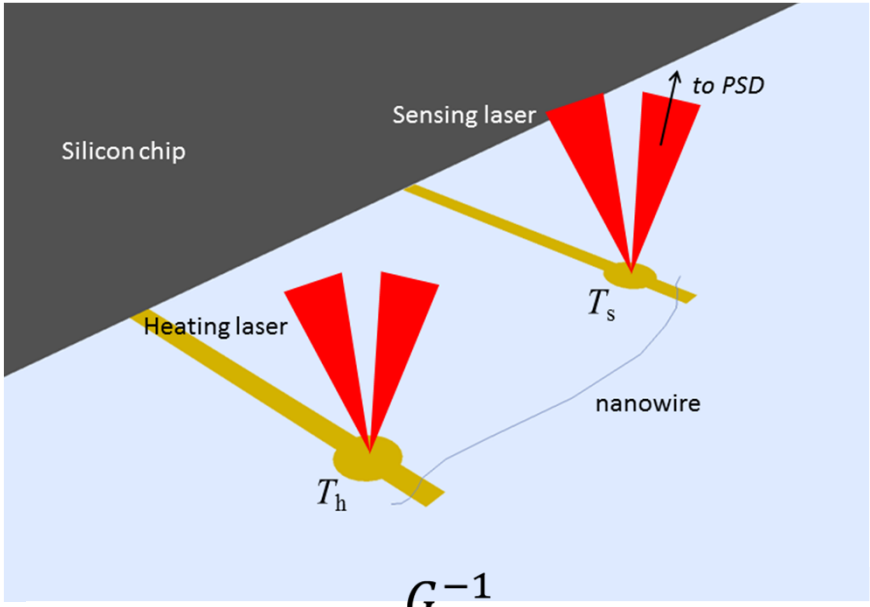
temperature resolution of 2.9 ± 0.7 μK

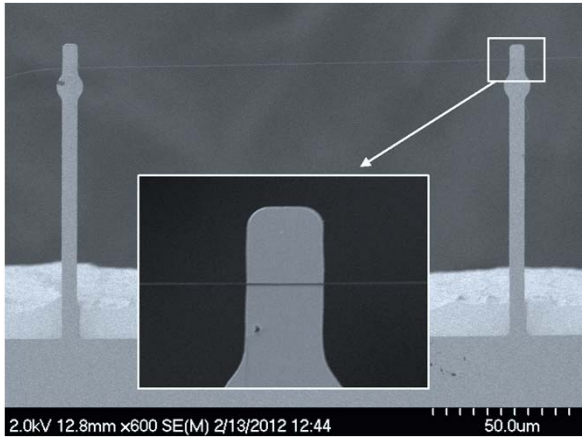
Canetta, C. and Narayanaswamy, A. Appl. Phys. Lett., 102 (2013)

Dual cantilever measurement technique

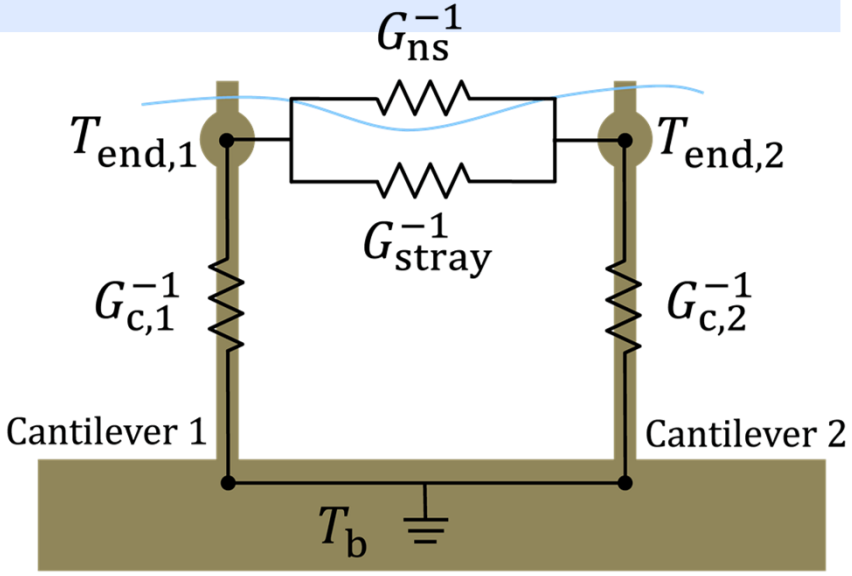


Source: L. Shi, D. Li, C. Yu, W. Jang, D. Kim, Z. Yao, P. Kim, and A. Majumdar, J. Heat Transf., 125 (2003)





Polystyrene nanofiber, diameter < 200 nm



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Canetta, C. and Narayanaswamy, A. Rev. Sci. Instrum., 84 (2013)