

Supplementary Information:

Fabrication and Characterization of Au(111)/Mica
Bimaterial Microcantilevers for Surface Sciences
Nanocalorimetry Applications

Piyush Kanti Sarkar^{a,*}, Sebastien Pinaud^a, Justine Harmel^a, Christophe Deshayes^a, Jimmy Faria^a, Laure Noé^a, Mathieu Gouhaut^b, Christian joachim^a

^a*Univ Toulouse, CNRS, CEMES, Toulouse, France*

^b*MUL Micro Usinage Laser, 20 Rue de la Gravette, 31150 Gratentour, France*

*Corresponding author: piyush.sarkar@cemes.fr

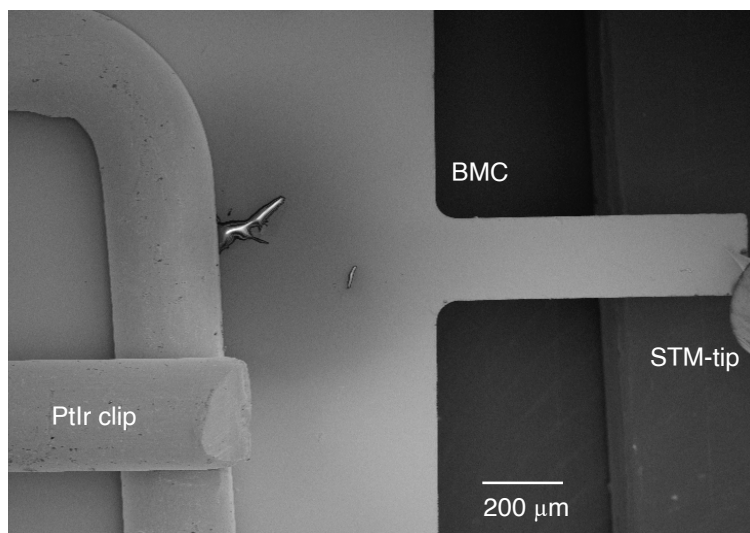


Figure S1: SEM image showing the STM-tip position on the BMC for Fig. 4 STM scan images.

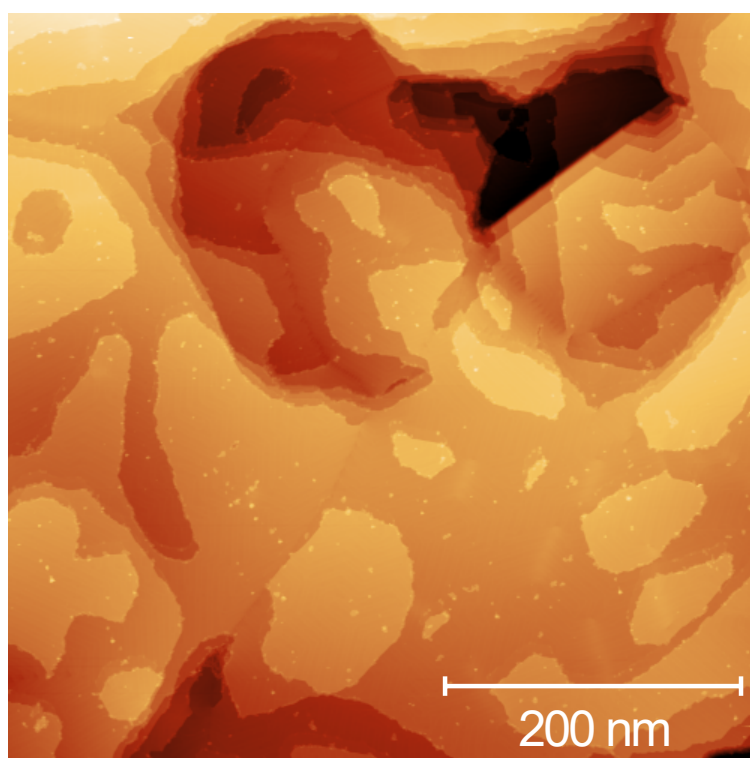


Figure S2: 77 K STM image of a 500 nm × 500 nm area of the Au(111) layer atop mica at the edge of the BMC suggests presence of large atomically flat terraces even at the edge of the BMC (Fig. S1). The BMC end is towards the right side of this image. $I = 10$ pA, $V_{bias} = 1$ V.

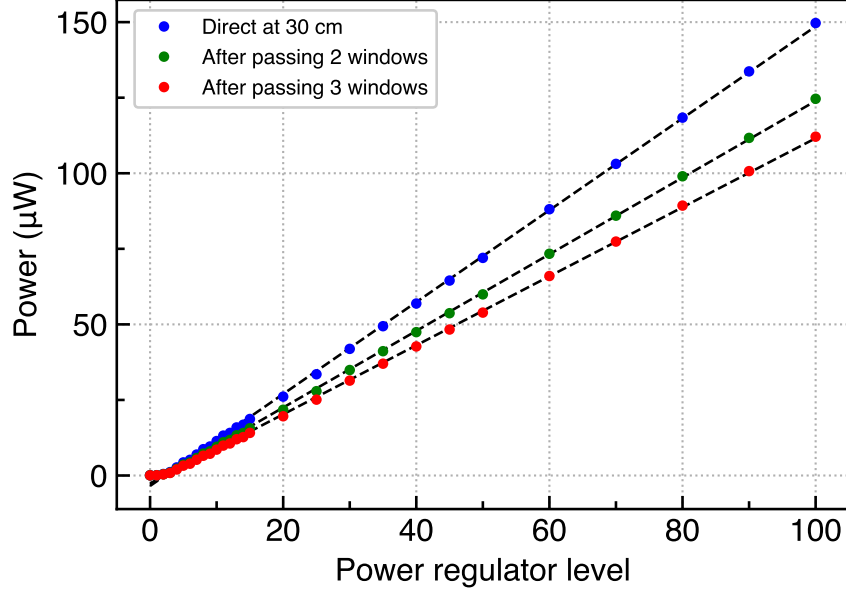


Figure S3: Laser power calibration outside the UHV system replicating similar conditions for the optical path as inside the UHV system.

S1 Estimating P_{abs} on Au(111)

Using the model proposed by Barnes et al. [1], when the power is absorbed on the whole Au(111) surface, the deflection is given by:

$$\Delta z = \frac{3}{4}(\alpha_{Au} - \alpha_{mica}) \frac{h_{Au} + h_{mica}}{h_{mica}^2 K} \frac{L^3}{w(\lambda_{Au} h_{Au} + \lambda_{mica} h_{mica})} P_{abs} \quad (\text{S.1})$$

where,

$$K = 4 + 6 \frac{h_{Au}}{h_{mica}} + 4 \frac{h_{Au}^2}{h_{mica}^2} + \frac{E_{Au}}{E_{mica}} \frac{h_{Au}^3}{h_{mica}^3} + \frac{E_{mica}}{E_{Au}} \frac{h_{mica}}{h_{Au}} \quad (\text{S.2})$$

Here, α : the coefficient of thermal expansion; h : thickness, and E : Young's modulus for gold and mica denoted by the subscript; L and w are length and width of the cantilever. $P_{abs} = \eta P_{in}$ where, η is the absorbance. After fitting our experimental data with this model and using the BMC geometry we found the η to be 0.097 (Fig. S4), i.e. about 10% of the incident power (P_{in}) is absorbed by the Au(111) surface of the BMC.

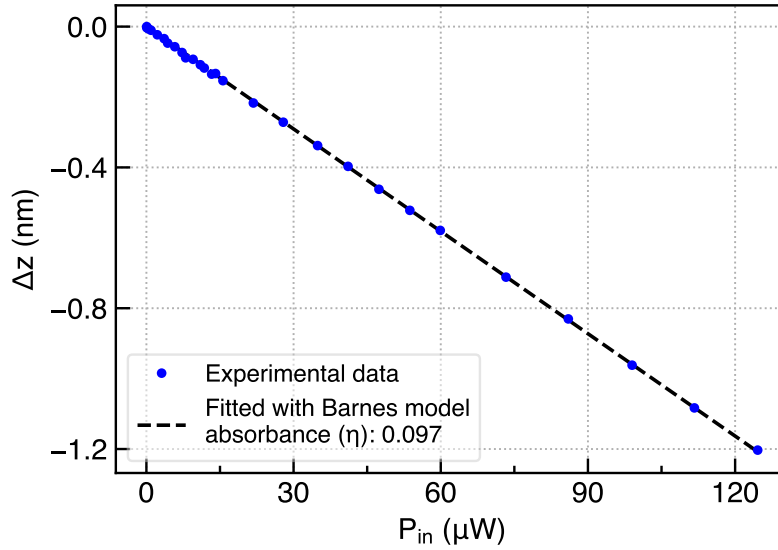


Figure S4: Deflection data fitted with Barnes model to calculate the power absorbed on the Au(111) surface.

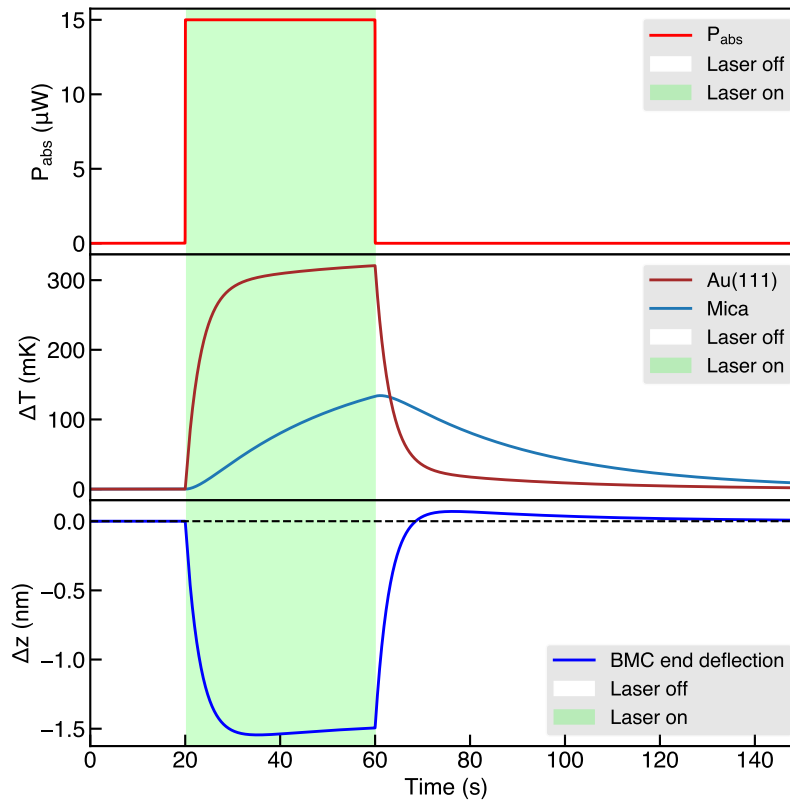


Figure S5: Calculated time evolution of the change in temperature in Au(111) and mica and the corresponding BMC-end deflection (Δz) in response to the laser on-off sequence using Timoshenko formula for our device geometry.

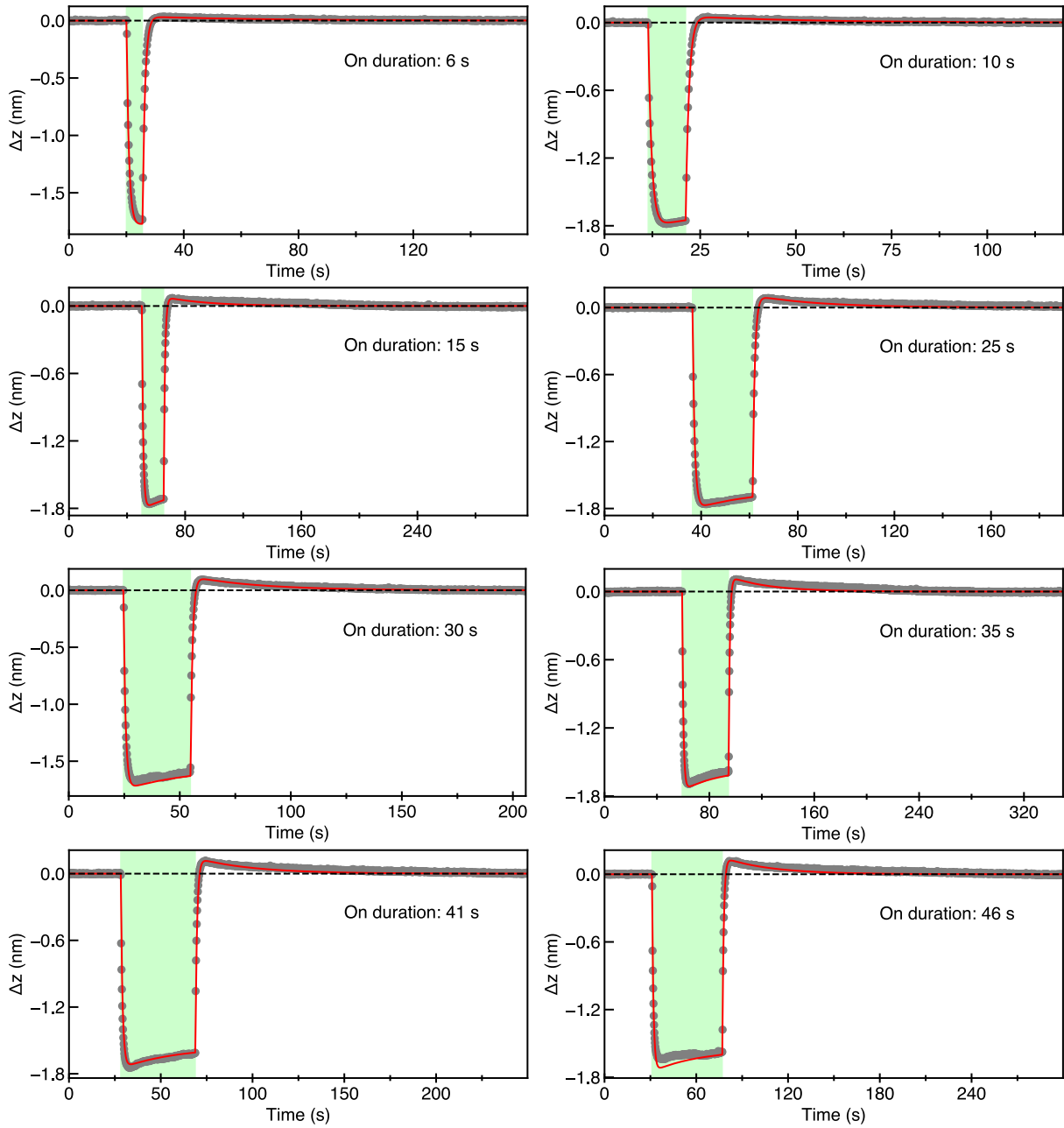


Figure S6: $\Delta z(t)$ deflection of the BMC for different laser illumination durations. Grey dots are experimental data and the red curve is calculated $\Delta z(t)$ using Timoshenko formula.

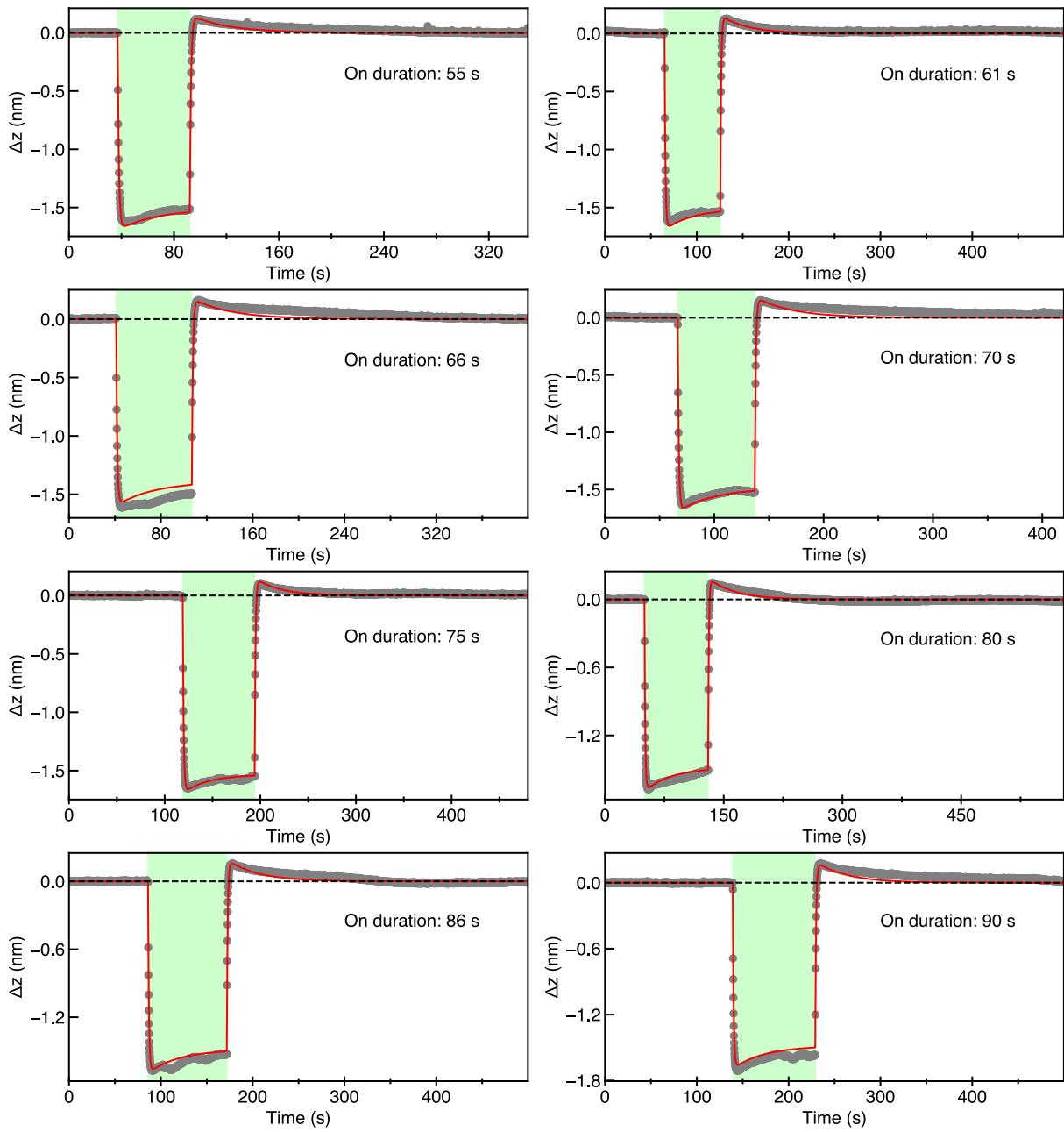


Figure S6: Continue.

S2 Nanocalorimetry sensitivity calculation

From equations S.1 and S.2, and considering our BMC geometry, the theoretical power sensitivity (S_P) is calculated to be 0.1 pm nW^{-1} . The experimental data also suggests the similar sensitivity considering the $\sim 10\%$ absorbance of the incident power. The energy sensitivity (S_E) can be calculated with the time constant of the deflection (τ) as:

$$S_E = \frac{S_P}{\tau} \quad (\text{S.3})$$

where the theoretical value for τ can be calculated with the device geometry and materials property as: [1]

$$\tau = \frac{C_{eff}}{G_{eff}} \quad (\text{S.4})$$

where, C_{eff} is effective heat capacity of the BMC and G_{eff} is the effective heat conductance to the sink which can be calculated as:

$$C_{eff} = (\rho_{Au}c_{p,Au}h_{Au} + \rho_{mica}c_{p,mica}h_{mica})Lw \quad (\text{S.5})$$

$$G_{eff} = G_{Au-sink} + \frac{G_{Au-mica}G_{mica-sink}}{G_{Au-mica} + G_{mica-sink}} \quad (\text{S.6})$$

where, ρ and c_p are density and specific heat, respectively, for gold and mica denoted by the subscript.

Using our device geometry and the fitted values for the conductances (section 5 in main manuscript), the time constant is calculated to be 132 ms, suggesting an energy sensitivity of 0.75 pm nJ^{-1} . With this sensitivity and high precision Δz allow our BMC to accurately measure energy as low as 5 nJ ($\sim 1 \text{ ncal}$).

References

- [1] J. R. Barnes, R. J. Stephenson, C. N. Woodburn, S. J. O'Shea, M. E. Welland, T. Rayment, J. K. Gimzewski, C. Gerber, A femtojoule calorimeter using micromechanical sensors, Review of Scientific Instruments 65 (12) (1994) 3793–3798. doi:10.1063/1.1144509.
URL <https://doi.org/10.1063/1.1144509>