Supplementary Information:

Optomechanical Resonating Probe for Very High Frequency Sensing of Atomic Forces

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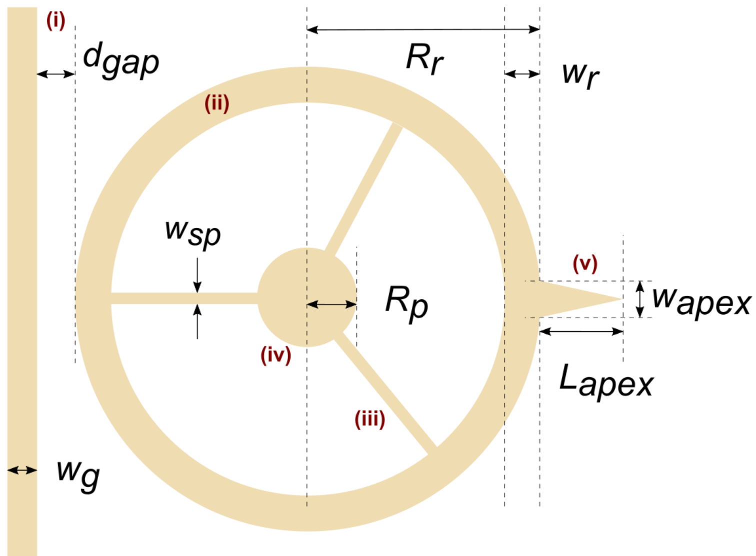

Figure S1. Details of the probe design. (i) Waveguide. (ii) Ring optomechanical resonator. (iii) Spokes. (iv) Pedestal. (v) Probe apex. w_g: width waveguide. d_{gap}: gap between waveguide and ring. R_r: Ring radius. w_r: ring width. w_{sp}: width of the spokes. R_p: pedestal radius. w_{apex}: base width of the OM probe apex. L_{apex}: Length of the OM apex. For experiments presented in the main text: w_g= 400 nm, d_{gap}= 300 nm, R_r= 10 µm, w_r= 750 nm, R_p= 1.5 µm, w_{sp}=w_{apex}= 500 nm, L_{apex}= 4 µm.

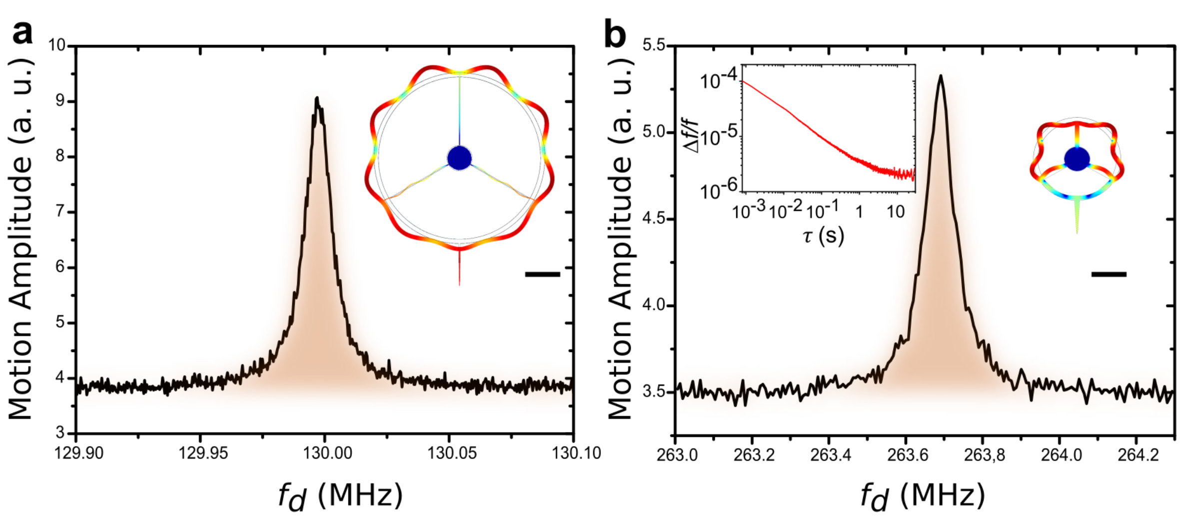

Figure S2. Motion amplitude (R_1) of other probes characterized in the Brownian regime (V_d=0 V). a, Softer probe f=130 MHz, k~7 kN/m, R_r=10 µm, w_r=500 nm, w_{sp}=100 nm, w_{apex}=100 nm, L_{apex}= 4 µm, Filter BW=1kHz. The modal stiffness of the probe has been reduced by placing the apex at an anti-node of displacement of the ring, which we technologically achieve in a reproducible manner thanks to ~10 nm positioning precision in the fabrication process. **b**, Higher frequency probe f=263.7 MHz, k~143 kN/m. R_r=5 µm, w_r=500 nm, w_{sp}=500 nm, w_{apex}=100 nm, L_{apex}= 4 µm, Filter BW=1 kHz. Inset: Allan deviation of the normalized mechanical frequency shifts $\Delta f/f$ showing the relative accuracy of the probe's measurement in open loop for V_d=200 mV. BW=100 kHz. Scale bars: 3 µm.

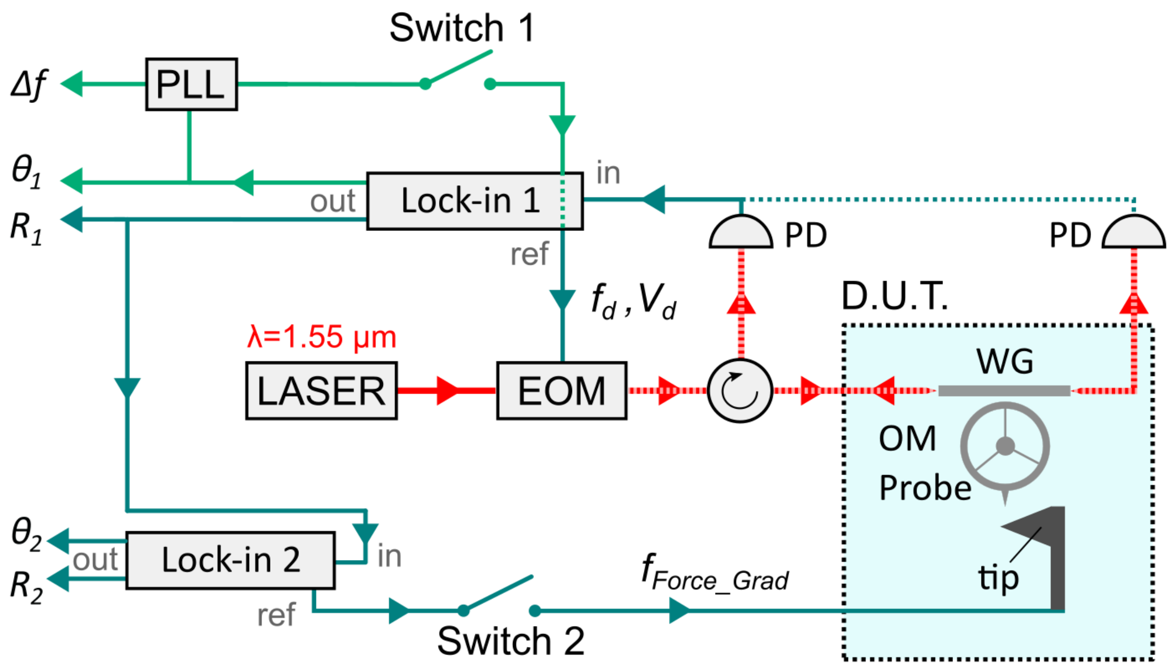

Figure S3. Bloc diagram of the experimental setup. Laser light used to excite the optomechanical (OM) probe is modulated by an electro-optic modulator (EOM) driven at frequency f_d. The device under test (DUT) can be accessed either in optical reflection or transmission. The experiments reported in the main text were carried in reflection from the waveguide, using a fibered optical circulator. The information imprinted by the OM probe motion onto the collected light is converted into a RF signal by a photodetector (PD) and sent to a lock-in amplifier (Lock-in 1). The complex component $R_1e^{i\Theta_1}$ at f_d of this signal exits Lock-in 1. In phase-locked loop (PLL) configuration (switch 1 closed), Θ_1 is fed-back to a PLL instrument to lock f to f_d. In absence of phase-locking (Figure 3c), Θ_1 is converted to Δf using the slope of the phase rotation versus frequency. In the force modulation experiment, R_1 is fed to Lock-in 2. The component of R_1 at the force modulation frequency f_{Force} is extracted: in Figure 5 R_2 is plotted versus f_{Force}. The table of correspondence between the bloc diagram and experimental data reported in the main text is given in Table S1.

Table S1. Table of correspondence of plotted physical quantities.

Figure	Plotted quantity			Switch 1	Switch 2	V_d	
Figure 3	**a:** R1	**b:** max(R1)	**c:** $(f-f_0)/f_0$	open	open	**a, b:** 0→750 mV	**c:** 200 mV
Figure 4	$(f - f_0)/f_0$ with $f = f_d$			closed	open	200 mV	
Figure 5	$\lvert(R_{2\_IN}\, e^{i\theta_{2\_IN}} - R_{2\_OUT}\, e^{i\theta_{2\_OUT}})/H_{\_LPF}\rvert$			open	closed	750 mV	

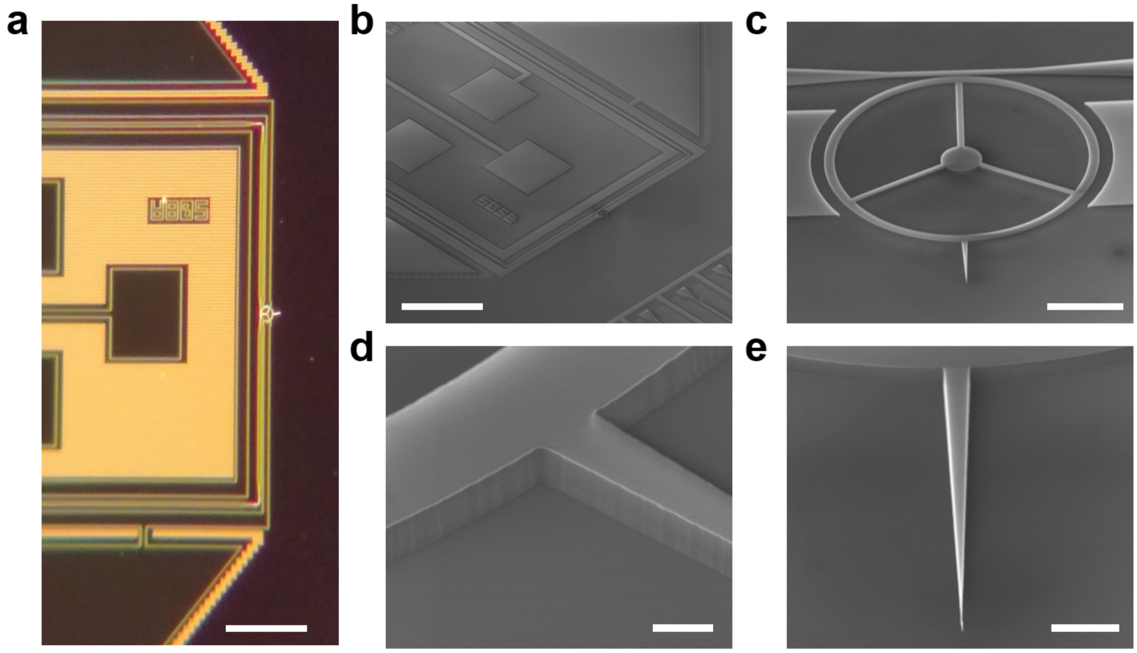

Figure S4. Images of devices fabricated using the VLSI technology. **a**, Optical microscope top view of a boat-shaped ultra-fast optomechanical probe device. Scale bar: 116 µm **b**, SEM monograph of the device bow. Scale bar: 100 µm **c**, Zoomed image of an optomechanical ring probe. Scale bar: 3 µm **d**, Zoomed image of the apex's base before under-etching. Scale bar: 400 nm **e**, Zoomed image of the apex. Scale bar: 800 nm. w_g= 620 nm, d_{gap}= 100 nm, R_r= 10 µm, w_r= 750 nm, R_p= 1.5 µm, w_{sp}= 400 nm, w_{apex}= 400 nm, L_{apex}= 5 µm.