

# Dissipation in Optomechanical Resonators

Quantum optomechanics [1-3] is a rapidly expanding field of research, combining quantum optics with optomechanical coupling in order to generate and detect quantum states of micro- and nanomechanical devices. Recent experiments have demonstrated mechanical laser cooling down to the level of only a few thermal quanta [4-8] and theory predicts that the quantum ground state can be reached with this method [9-11]. At present, however, the rate of thermalization prevents laser cooling to the vibrational ground state. In order to overcome this barrier, the impact and sources of mechanical damping in these devices must be quantified.

In this application, G.D. Cole and M. Aspelmeyer of the University of Vienna have analyzed the acoustic dissipation of microresonators using a cryogenic interferometry setup, see Fig. 1. In detail, their system utilizes a continuous flow <sup>4</sup>He cryostat as sample chamber equipped with a stack of attocube's ANPxyz51 positioners for aligning the sample with respect to an optical fiber. This fiber is part of a homodyne interferometer, allowing high signal-to-noise measurements of the eigenmodes of the resonator (Fig. 2) while keeping disturbances due to radiation pressure and optical fluctuations at a minimum. The turbo-pumped cryostat enables interrogation from room temperature (RT) to 20 K, and from atmospheric pressure to vacuum levels of  $2.5 \times 10^{-7}$  millibar.

Cole & Aspelmeyer take advantage of a piezo-electric disc to excite the optomechanical resonator, either broad band by white noise or resonant at a specific frequency. While the first method allows to characterize the resonance spectrum of the resonator, the second accurately yields the ringdown time for a single resonance and therefore its quality factor Q. Fig. 3 depicts this information for a resonator eigenmode with a frequency close to 4 MHz, demonstrating a Q factor of  $8 \times 10^4$ . To simultaneously achieve high Q and high reflectivity, the optomechanical resonators are fabricated from an epitaxial  $Al_xGa_{1-x}As$  Bragg reflector. This technique results in reflectivities exceeding 99.98% at 1064 nm, providing the basic requirement for optical ground-state cooling.

In summary, an experimental setup used to characterize the properties of a micro-optomechanical resonator with resonance frequencies of up to 4 MHz and Q-factors as high as  $8 \times 10^4$  is described in this application note. A stack of attocube ANPxyz51 positioners is used to precisely position the resonator with respect to an optical fiber, forming one arm of a homodyne interferometer.

**References:**

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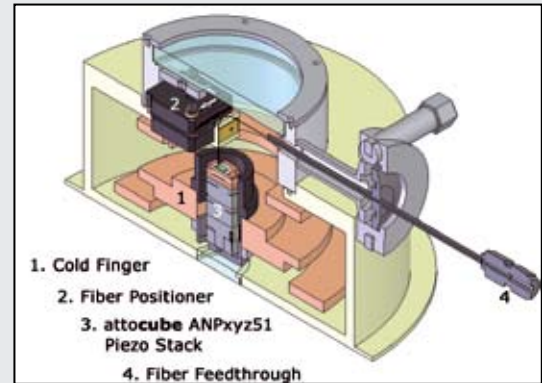


Fig. 1: Schematic of the experimental setup: the sample chip (green) is placed in a continuous flow <sup>4</sup>He cryostat and positioned underneath an optical fiber using an ANPxyz51 positioner stack. The resonator is piezoelectrically excited and its vibrational modes are detected using homodyne fiber interferometry (not shown).



Fig. 2: Scanning electron microscope image of the optomechanical resonator, fabricated from epitaxially grown  $Al_xGa_{1-x}As$ .

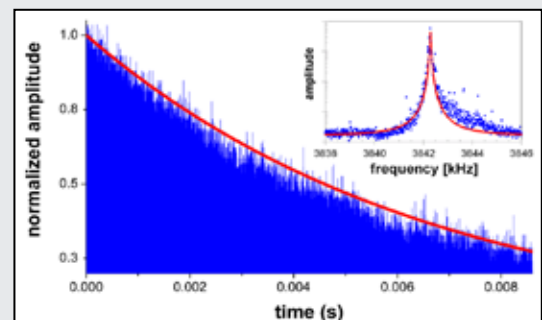


Fig. 3: Experimental ringdown of a  $100 \times 50 \mu m^2$  resonator stack measured at 20 K and  $2.5 \times 10^{-7}$  mbar. The exponential fit (red) yields a Q value of  $\approx 80000$ .

Fig. 1-3 courtesy of G.D. Cole/M. Aspelmeyer, Univ. of Vienna.

**RELATED PRODUCTS**

- ANPxyz51/LT/HV linear stepper positioners providing highest stability
- ANC300/3 piezo positioning controller

