Master thesis: **Mechanical break junctions for quantized conductance and Raman scattering**

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Laboratory of Quantum Nano Optics by Prof. Galland, https://www.epfl.ch/labs/lqno/
Project type: Master thesis or Internship
Start date: Fall 2026 or sooner
Deliverables: Thesis or final report and defense or presentation

Overview

Nanometer and sub-nanometer metallic gaps are very interesting devices for manipulating electromagnetic fields, as within such small gaps strong electric fields can be created by applying small voltages. This is valid for static and quasistatic fields at low frequencies as well as for frequencies of several 100 THz in the visible [1]. Precise control over the gap distance is thus both scientifically and technologically interesting. One way to achieve precise gap control is to use mechanical break junctions where a thin gold nanowire is sitting on top of a flexible substrate [2], see Figure 1a). By bending the substrate the nanowire is first elongated, until a single atom connects the two ends and finally a gap is opened whose distance can be precisely controlled see Figure 1b). This can be seen through the current conductance going from standard ohmic resistance to a ballistic transport over to tunneling, see Figure 1c). The challenge is to create this gap opening process as smooth as possible while avoiding a sudden rupture of the nanowire.

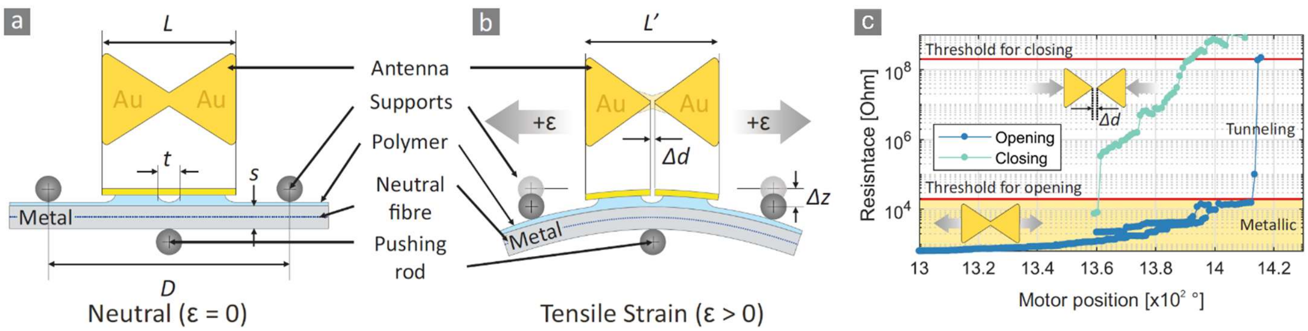

Figure 1a) Overview of mechanical break junction with no stretching showing a connected constriction in the center of the device. b) When the substrate is bent the junctions are first elongated until a gap is opened in the constriction. c) This gap opening is monitored through the resistance of the device. Figure adapted from [3].

Tasks

Thanks to our collaborators from IBM [2,3], we have both a setup as well as samples to make the mechanical break junction feasible. In a first step the student will thus need to familiarize themselves with the setup and manage to reliably open and close the mechanical break junction, while monitoring the electrical conductance.

Once the electrical part is mastered the student will integrate the mechanical break junction setup with an optical setup, allowing them to measure the optical properties of the mechanical break junction. Finally if time permitting, the student will add molecules to the break junction and measure the Raman scattering in function of the gap opening and closing, allowing us to correlate the Raman intensity versus conductance and to elucidate the origin of the so called picocavities[4].

We are looking for motivated students with a background in physics, electrical engineering or similar. If you are interested in the project and you want to know more, please do not hesitate to contact us. We are looking forward to hear from you.

[1] Baumberg, Jeremy J., Javier Aizpurua, Maiken H. Mikkelsen, and David R. Smith. “Extreme Nanophotonics from Ultrathin Metallic Gaps.” *Nature Materials* 18, no. 7 (2019): 668–78. https://doi.org/10.1038/s41563-019-0290-y.

[2] Schwarz, Florian, and Emanuel Lörtscher. "Break-junctions for investigating transport at the molecular scale." *Journal of Physics: Condensed Matter* 26.47 (2014): 474201.

[3] Gruber, Cynthia M. *Top-down Fabricated and Mechanically Actuated Field-enhancing Optical Antennas for Investigating Plasmon-Plasmon Interactions and Molecular Raman Scattering*. Diss. ETH Zurich, 2018.

[4] Baumberg, Jeremy J. “Picocavities: A Primer.” *Nano Letters* 22, no. 14 (2022): 5859–65. https://doi.org/10.1021/acs.nanolett.2c01695.