Probing superconductivity at very low temperature and high pressure using NV centers in diamond

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Abstract

High pressure enhances quantum properties of materials such as the superconductivity of cuprates[1], nickelates[2] and superhydrides[3]. The diamond anvil cell (DAC) is a tool that allows to create pressure comparable to those existing in the Earth core, above the megabar range (100 GPa). However, it sets heavy constraints on the methods available for in-situ characterization. By implanting nitrogen-vacancy (NV) centers on the tip of a diamond anvil, we demonstrated that it is possible to study high pressure magnetic or superconducting phase transitions with high sensitivity and micrometer spatial resolution. In the case of superconductivity, we can probe and map the expulsion of an external magnetic field when the temperature decreases below the critical temperature, also called Meissner effect[4].

In collaboration with Attocube Systems AG (Germany), we have developed an original, high-performance and versatile experimental platform for studying superconductivity of materials at high pressure and very low temperature (starting at 4K). The platform is an optical, closed-cycle Helium cryostat compatible with membrane DACs, providing a precise and independent control of pressure and temperature. Moreover, it is equipped with a 500 mT vector superconducting magnet.

We present critical temperature measurements performed on a MgB_2 powder at high pressure using this platform. We observe a linear decrease of the critical temperature with pressure from 35 K at 0 GPa down to 14 K at 25 GPa, in agreement with the literature[5]. Above 25 GPa, the superconducting phase of MgB_2 seems to disappear, according to our current measurements. Further measurements will be performed to study in detail this process.

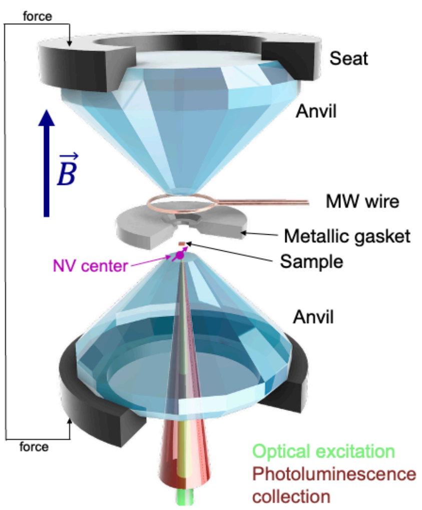

Figure 1. Scheme of the DAC, showing the main components and sample configuration.

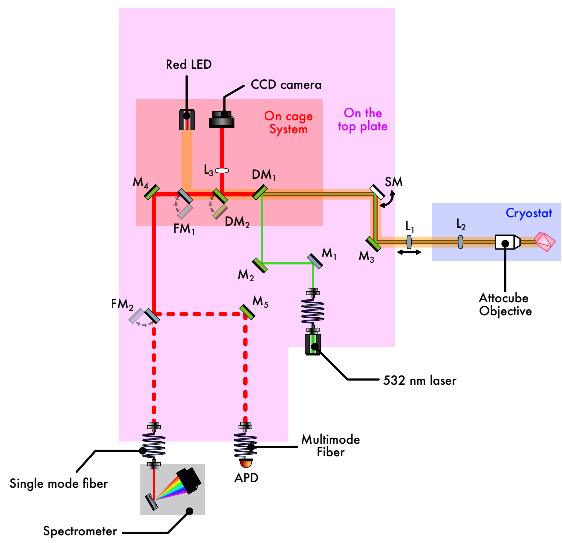

Figure 2. Scheme of the experimental setup.

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[2] H. Sun, *et al.* **Nature 621** (2023), 493.
[3] M. Somayazulu, *et al.* **Phys. Rev. Lett. 122** (2019), 027001.
[4] C. Dailledouze, *et al*. **Phys. Rev. Applied 23** (2025), 064067.
[5] Cristina Buzea and Tsutomu Yamashita **Supercond. Sci. Technol. 14** (2001), R115.