Implementation of double-sided laser heating through diamond anvil cells in radial geometry at COMPRES supported ALS beamline 12.2.2

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High-pressure X-ray diffraction through diamond anvil cells in radial geometry (r-DAC), pioneered by - like almost anything related to diamond anvil cells – Bassett [1] and further developed mainly by Wenk [2-4] and co-workers has become a standard tool to investigate the deformation behavior, rheological properties and strength of materials at the conditions of the Earth's interior [5-7] This class of experiments is important in the quest to find a geological interpretation for seismic profiles of the Earth and to quantify the large-scale convection of the Earth's mantle, which in turn is linked to the driving force behind plate tectonics. The main criticism of initial work with r-DAC's was that experiments were performed at room temperature and therefore were at best only qualitatively relevant for lower mantle processes. This criticism was initially addressed by two approaches: 1) an in situ single-sided laser heating set up [8] designed and implemented at the ALS, and 2) a resistively heated radial diffraction DAC [9] at DESY. Axial temperature gradients and limited maximal temperatures, respectively, are drawbacks of these two approaches. A double-sided in situ laser heating set-up based on the laser and pyrometry optics mounted on a rotational stage was proposed at HPCAT [10] but to the best of our knowledge never implemented.

In this contribution, we present the implementation of a user friendly in-situ double-sided laser heating compatible with radial X-ray diffraction for texture, strength and rheology measurements at COMPRES supported beamline 12.2.2 of the Advanced Light Source (ALS) at Lawrence Berkeley Lab. The system builds on the existing axial set up [11]. Laser and imaging paths are redirected in the horizontal from a 0°/180° direction to a 90°/270° setting. The 90° redirection involves the insertion of a small periscope mirror pair with an objective lens into the axial downstream beampath. This is fully motorized and can be achieved remotely. The 270° beampath on the other hand involves the removal of the upstream axial objective lens and the manual installation of a small rig carrying 2 IR mirrors and the objective lens. Installation and alignment is straight forward and can be accomplished in less than one hour. System response calibration is stable for months and is done with a calibrated W-lamp. For temperature measurement, we employ the peak scaling method [12]. This allows the establishment of 2-dimensional temperature maps and thus temperature gradients in quasi real time.

Examples of in-situ measurements at high pressure and high temperatures will be presented.

1. Kinsland, G.L. and W.A. Bassett, *Modification of the diamond cell for measuring strain and the strength of materials at pressures up to 300 kilobar.* Review of Scientific Instruments, 1976. **47**(1): p. 130-133.
2. Merkel, S., et al., *Deformation of polycrystalline iron up to 30 GPa and 1000 K.* Physics of the Earth and Planetary Interiors, 2004. **145**(1-4): p. 239-251.
3. Wenk, H.-R., et al., *The plastic deformation of iron at pressures of the Earth's inner core.* Nature, 2000. **405**(6790): p. 1044.

4. Wenk, H.-R., et al., *Deformation in the lowermost mantle: From polycrystal plasticity to seismic anisotropy.* Earth and Planetary Science Letters, 2011. **306**(1-2): p. 33-45.
5. Marquardt, H. and L. Miyagi, *Slab stagnation in the shallow lower mantle linked to an increase in mantle viscosity.* Nature Geoscience, 2015. **8**(4): p. 311.
6. Miyagi, L., et al., *Slip systems in MgSiO3 post-perovskite: implications for D'' anisotropy.* Science, 2010. **329**(5999): p. 1639-1641.
7. Xie, M., et al., *Lattice stress states of superhard tungsten tetraboride from radial x-ray diffraction under nonhydrostatic compression.* Physical Review B, 2014. **90**(10): p. 104104.
8. Kunz, M., et al., *In situ laser heating and radial synchrotron x-ray diffraction in a diamond anvil cell.* Review of scientific instruments, 2007. **78**(6): p. 063907.
9. Liermann, H.-P., et al., *Experimental method for in situ determination of material textures at simultaneous high pressure and high temperature by means of radial diffraction in the diamond anvil cell.* Review of scientific instruments, 2009. **80**(10): p. 104501.
10. Meng, Y., G. Shen, and H. Mao, *Double-sided laser heating system at HPCAT for in situ x-ray diffraction at high pressures and high temperatures.* Journal of Physics: Condensed Matter, 2006. **18**(25): p. S1097.
11. Kunz, M., et al., *Implementation and application of the peak scaling method for temperature measurement in the laser heated diamond anvil cell.* Review of Scientific Instruments, 2018. **89**(8): p. 083903.
12. Rainey, E. and A. Kavner, *Peak scaling method to measure temperatures in the laser-heated diamond anvil cell and application to the thermal conductivity of MgO.* Journal of Geophysical Research: Solid Earth, 2014. **119**(11): p. 8154-8170.