Mid-Infrared Spectroscopy of Laser-Produced Impact Melts. A. Morlok[1], C.Hamann[2], D. J. P. Martin[3], K. H. Joy[3], R.Wogelius[3], I. Weber[1], A. Stojic[1], H.Hiesinger[1], J.Helbert[4] [1]Institut für Planetologie, Wilhelm-Klemm-Strasse 10, 48149, Münster, Germany [2] Museum für Naturkunde, Invalidenstrasse 43, 10115 Berlin, Germany [3]School of Earth and Environmental Sciences, University of Manchester, Oxford Road, Manchester M13 9PL, UK [4]Institute for Planetary Research, DLR, Rutherfordstrasse 2, 12489 Berlin, Germany.

Introduction: The IRIS (Infrared and Raman for Interplanetary Spectroscopy) laboratory regularly produces spectra for a database for the ESA/JAXA Bepi-Colombo mission to Mercury. Onboard is a mid-infrared spectrometer (MERTIS-Mercury Radiometer and Thermal Infrared Spectrometer). This unique device allows us to map spectral features in the 7-14 µm range, with an average spatial resolution of ~500 m [1-4]. With these infrared spectra the mineralogical makeup of the planetary surface can be determined via remote sensing. The surface of Mercury has been exposed to heavy impact cratering throughout its history [4] and impact products are likely to form a an important component of its surface regolith. Mercury is expected to have glass contents of up to 45%, much higher than, e.g., on the lunar regolith (2-5%) [5]. We are undertaking a series of mid-IR spectroscopy studies on shocked minerals and glass in the laboratory environment, in order to help interpret future MERTIS measurements [6-9].

Samples and Techniques:

Sample Selection: The microstructure of glass lacks a far-range order of its molecular constituents and represents the most amorphous phase of a given chemical composition. Impact melt glass is typically generated by events involving high (post) shock pressure and temperatures [10,11]. Impact melt glasses from impacts into basaltic rocks are rare, hence we simulated impact melting of basaltic materials using laser irradiation [12]. Specifically, we used Hoffelder basalt (Hoffled, Germany) as starting material, a basanitic (Na_2O + $K_2O \approx 5$ wt%; $SiO_2 \approx 44$ wt%), porphyritic rock consisting of 200–800 µm size olivine (Fo79±4) phenocrysts set in an aphanitic groundmass (≤100 µm grain size) of labra-dorite (An62Ab36Or2), salite (En39±3Fs13±1Wo49±2), Fe,Ti oxides (ulvöspinel ± rare ilmenite), and feldspathoids [12].

Laser Melting: A pulsed Nd:YAG laser was used at Technische Universität Berlin to irradiate the samples along 15 mm long and 1 mm wide lines. Laser settings were optimized for melt production: the emitted power was 0.9 kW over 15 s at a wavelength of 1064 nm, a pulse frequency of 25 Hz, and a pulse duration of 2.5 ms. Sample runs were collected, embedded in resin, sec-tioned, and polished.

FTIR-Spectroscopy: The small sample sizes of most of the material required micro-FTIR analyses. Here we used a Perkin-Elmer Spotlight-400 FTIR spectrometer At the University of Manchester. Spot analyses (25 × 25 µm) were made in the wavelength range from 2.5 to 15.4 µm in the reflectance mode, using a cooled mercury-cadmium-telluride (MCT) detector. For the mapping of an area (Fig.1 and 2) on a polished section, an adjoining micro spectroscopy mapping unit was used.

Results: Basaltic glass shows very simple spectra (Fig. 3), dominated by one broad Reststrahlen band (RB) between 10.1 and 10.5 µm, and a Christiansen feature (CF) from 8.3 to 8.5 µm. Fine-grained parts of the basalt show more variation; here the dominating RB (9.7 – 10.1 µm) is accompanied by additional bands from 8.9 – 9.4 µm and 10.2 –10.4 µm. The CF is between 7.9 and 8.3 µm. Minor bands are located at longer wavelengths from 13.1 to 16.7 µm (in the bulk spectrum). Larger crystals show a wider distribution of features, in part due to crystal orientation effects. The CF is between 8.2 and 9.1 µm, various major RB are at 9.3 – 9.5 µm, 9.6 – 10 µm, 10.2 – 10.4 µm, 10.6 – 10.9 µm, 11 - 11.2 µm, and 11.9 – 12 µm, with additional minor features between 13 and 16.2 µm (in the bulk spectrum).

Discussion: Band positions for the melt glass are consistent with those of basaltic glass in earlier studies [6, 13]. The main RB features of the fine grained unmelted basalt groundmass is shifted to shorter wavelengths compared to the melt glass, 9.7 – 10.1 µm compared with 10.1 – 10.5 µm. The melt glass shows a more mafic composition probably due to the inclusion of more and/or larger crystalline olivine grains into the melt. This difference in band positions of strong, clearly identifiable bands allows the distinction of impact melt glass from the other dominating components in the basalt, i.e, the fine-grained matrix or the olivine phenocrysts. The band positions in the phenocrysts are mostly those of olivine [14], with the exception of the band at 9.6 – 10.0, which is a pyroxene band [15].

Conclusions: First mid-infrared investigations give clear distinct spectroscopic signatures for the melted and unmelted components in the sample, which could help distinguishing impact shocked lithologies in basalt from pristine igneous material. However, as glass will be only a part of the mineral mixture in the regolith, further components will have to be taken into account.

The results will be made available via a database [16]

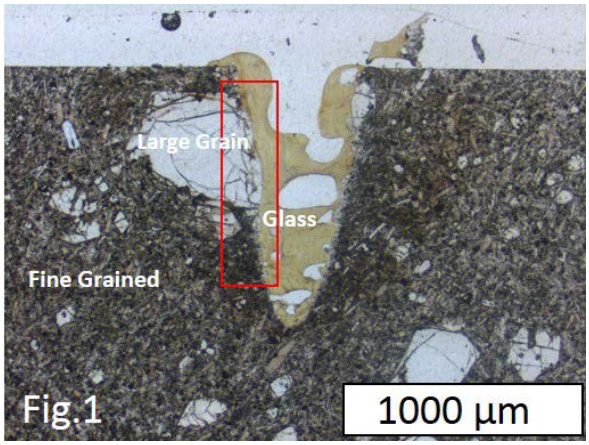

Figure 1. Cross section through one of the laser melted spots on the basalt slab (thin section). The melt glass is the brownish area in the center, surrounded by a fine grained-matrix and larger olivine grains. The box is the area analyzed using the scanning mode of the FTIR.

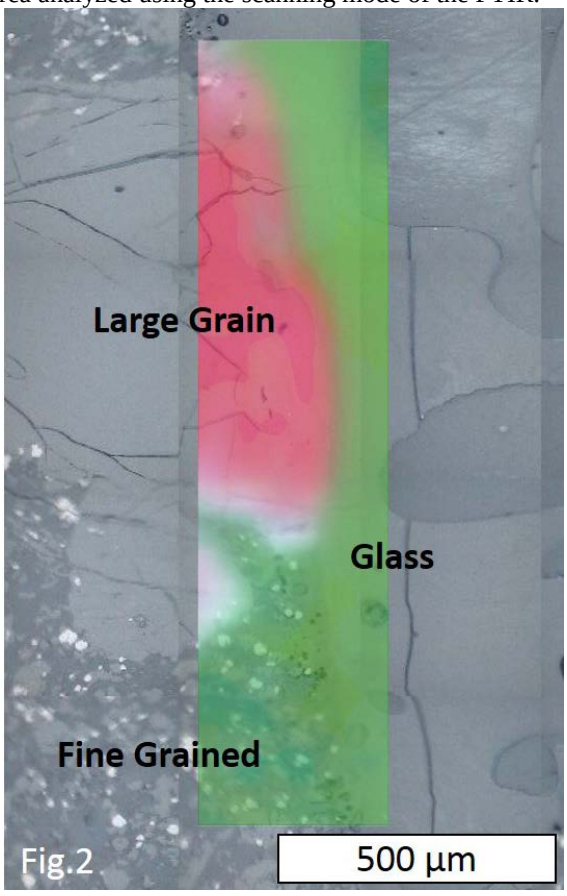

Figure 2. A 300 × 1000 µm sized area was scanned using the imaging mode of the FTIR. A Principal Component Analysis (PCA) multivariate statistical routine helped to identify the typical phases in this area, which are color coded (dark green = fine grained, bright green = glass, red = single olivine crystal).

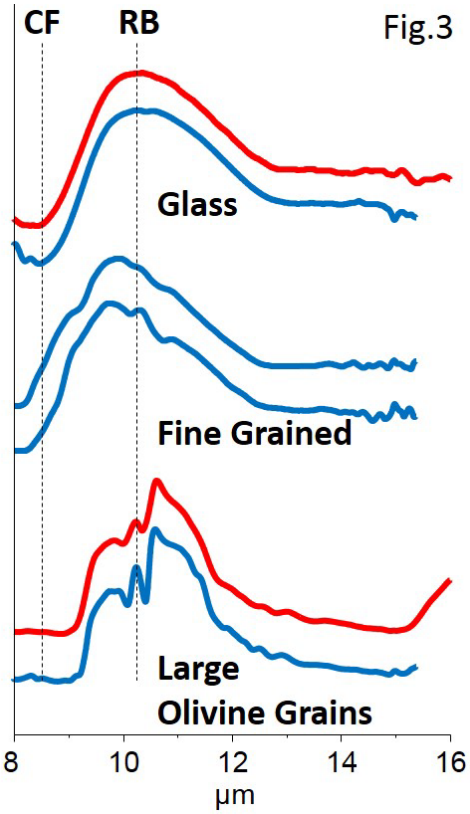

Figure 3. Resulting micro-FTIR spectra from the pristine and melted parts of the basalt slab. Red = single point analyses (25 × 25 µm), blue = phases identified using PCS analyses of scanned areas.

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References: [1] Maturili A. (2006) Planetary and Space Science 54, 1057–1064 [2] Helbert J. and Maturilli A. (2009) Earth and Planetary Science Letters 285, 347-354 [3] Benkhoff, J. et al. (2010) Planetary and Space Science 58, 2-20 [4] Hiesinger H. et al. (2010) Planetary and Space Science 58, 144–165 [5] Warren, P. (2008) Geochimica et Cosmochimica Acta 72, 3562-3585 [6] Morlok A. et al. (2017) Icarus 296, 123-138 [7] Morlok A. et al. (2016) Icarus 278, 162-179 [8] Martin, D.J.P. (2017) Meteoritics & Planetary Science 52, 1103-1124 [9] Pernet-Fisher, J.F. (2017) Scientific Reports 7 [10] Johnson J.R. (2012) Icarus 221, 359–364 [11] Lee R.J. et al. (2010) Journal of Geophysical Research 115, 1-9 [12] Hamann C. et al. (2016) Journal of Geophysical Research 43, 10602-10610 [13] DuFresne C.D.M. et al. (2009) American Mineralogist 94, 1580-1590 [14] Hamilton, V.E. (2010) Chemie der Erde 70, 7-33 [15] Hamilton V.E. (2000) Journal of Geophysical Research 105, 9701-971 [16] Weber I. et al. (2018) 49th LPSC Abstract #1430