

**Telescopic Raman Measurements of Glasses of Mineral Compositions to a Distance of 10 Meters** S. K. Sharma<sup>1</sup>, G. H. Beall<sup>2</sup>, H. W. Hubble<sup>1</sup>, A. K. Misra<sup>1</sup>, C. H. Chio<sup>1</sup> and P. G. Lucey<sup>1</sup>, <sup>1</sup>Hawaii Institute of Geophysics and Planetology, University of Hawaii, Honolulu, HI, 96822. (sksharma@soest.hawaii.edu), <sup>2</sup>Corning Incorporated, One Riverfront Plaza, Corning, NY 14831.

**Introduction:** Reflectivity spectra of Martian bright regions and laboratory experiments on synthetic glasses have indicated the presence of glass on the surface of Mars [1-3]. Glass formation on Mars can be from both volcanic and impact processes. Because of the broad nature of the reflectance bands, the exact composition and amount of glass on the surface of Mars is still a subject of discussion. The Martian meteorites (SNC, Shergottite-Nakhilite-Chassignite) contain diaplectic glass “maskelynite” formed by shock melting of feldspars. For example, in Shergottite the composition of maskelynite is normally in the range anorthite (An) 45 % to An 60 % (An<sub>45</sub> to An<sub>60</sub>), where An=CaAlSi<sub>3</sub>O<sub>8</sub>, with a few sodic outliers. Potassium is found to increase with albite (Ab, NaAlSi<sub>3</sub>O<sub>8</sub>) content [4-5]. Raman spectroscopy of isochemical minerals and glasses [e.g., 6-7], and micro-Raman measurements on thin-sections of Martian meteorite, have shown that Raman spectroscopy can easily distinguish between crystalline and glassy phases [8-9]. In this work, an improved version of a previously presented pulsed telescopic Raman system [10] has been used to explore the possibility of detecting and characterizing glasses of mineral compositions at a distance of ~10m. Remote Raman measurements are carried out on synthetic glasses along the join An<sub>100</sub> to An<sub>31</sub>, as well as on a glass sample of fused quartz.

**Equipment:** A pulsed telescopic Raman instrument (Fig. 1) for remote analysis of minerals on planetary surfaces is a modified version of an earlier instrument [10] developed at the University of Hawaii. The system consists of a 127mm telescope (Meade ETX-125 Maksutov Cassegrain, 125mm clear aperture, 1900mm focal length), a frequency doubled mini Nd:YAG laser source (Model ULTRA CFR, Big Sky Laser, 532nm, 35mJ, 20Hz), and a HoloSpec f/2.2 spectrometer equipped with a gated intensified detector (PI Model I-MAX-1024-E). The width of the laser pulses was approximately 8ns, and the beam divergence was less than 8mrad. Typical slit widths for Raman spectral measurements were 100 to 200 $\mu$ m. Samples were placed at distances ranging 8 to 10m from the telescope.

**Samples:** The fused quartz sample used for telescopic Raman measurement was a UV quality fused quartz circular (50mm diameter and 3mm thick) optical window. Samples of glasses along the join An-Ab were prepared at the Corning Inc., New York. Five compo-

sitions of glasses, An<sub>100</sub>, An<sub>75</sub>, An<sub>61</sub>, An<sub>50</sub> and An<sub>31</sub>, were prepared using high purity oxides and carbonates in appropriate amounts. The mixtures were fused at

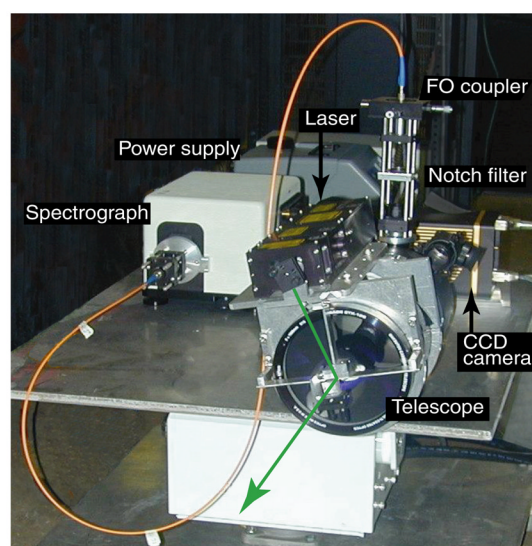
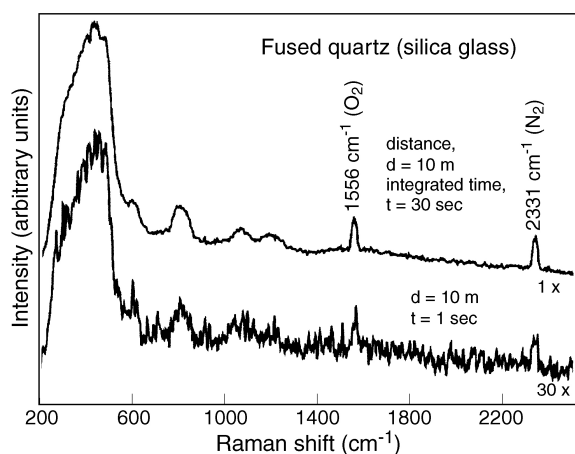


Fig. 1. Telescopic pulsed Raman instrument. The pulsed laser is mounted on the top of 125mm telescope. The orange Fiber-Optic (FO) cable transmits the Raman signal to the spectrograph equipped with a gated CCD detector.

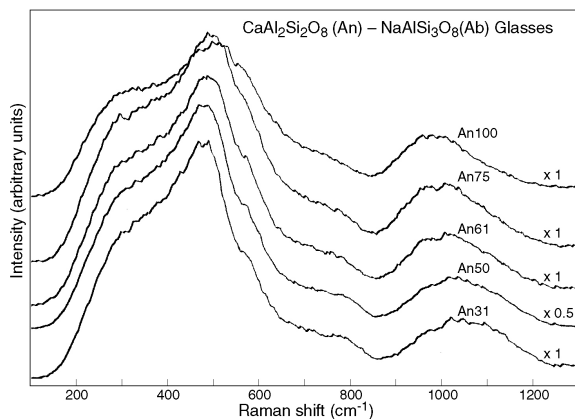
1650C in platinum crucibles and the melts were cast in patties and annealed at 700C. These glasses are homogeneous rectangular bars of 10cm x 4.2cm and 1.5cm thick, and have uneven but smooth surfaces. For Raman measurements these samples were used as received without any polishing.

**Results and Discussion:** Figure 2 depicts the Raman spectra of fused quartz measured from a distance of ~10m. The spectra are collected with a 30s integration time and have very good signal to noise ratio. Even the very weak and broad bands in the 1000 to 1200cm<sup>-1</sup> region due to antisymmetric stretching mode of bridging oxygen,  $\nu_{as}(\text{Si-O-Si})$ , are clearly visible in the spectrum (Fig. 2). The sharp lines at 1556 and 2331cm<sup>-1</sup> are the Raman lines of the atmospheric O<sub>2</sub> and N<sub>2</sub>, respectively. The strong band at 437cm<sup>-1</sup>, shoulders at 490 and 606cm<sup>-1</sup> in the spectrum of silica glass (Fig. 2) are attributed respectively to  $\nu_s(\text{Si-O-Si})$  symmetric stretching modes of the 6-membered, 4-membered and 3-membered rings of SiO<sub>4</sub> tetrahedra [6, 11-12].

Figure 3 depicts telescopic Raman spectra of glasses along the join An-Ab measured at a distance of  $\sim 10$  meter from the sample. These spectra have an excellent signal to noise ratio and were measured with gated detection using 100s (2000 laser shots) integration time, and 35mJ/pulse laser power @ 532nm. A comparison of the telescopic Raman spectrum of An<sub>100</sub> glass with previously published conventional Raman spectrum of glass of anorthite composition are overall similar except that in the low frequency region of the telescopic Raman spectra (Fig. 3) the use of 532nm holographic notch filter has significantly reduced the contribution from the Rayleigh tail.



**Fig. 2.** Telescopic unpolarized Raman spectra of silica glass measured at a distance of  $\sim 10$ m. Laser power 35mJ/pulse @ 532nm.



**Figure 3:** Telescopic unpolarized Raman spectra of glasses of plagioclase compositions.

The position of Raman bands of An-Ab glasses, determined by curve fitting the spectra with Gaussian shape bands, are given in Table 1. The strongest 504

$\text{cm}^{-1}$  band of An<sub>100</sub> glass corresponds to  $\nu_s(\text{T-O-T})$  symmetric stretching modes of 4-membered rings of  $\text{TO}_4$  tetrahedra, where T = Si or Al. This band shifts with decreasing amount of An components in the glass and appears at  $473 \text{ cm}^{-1}$  in the spectrum of An<sub>31</sub> glass, because of the formation of the 6-membered  $\text{TO}_4$  rings in the glass. The bands in the  $\nu_{as}(\text{T-O-T})$  doublet also show composition dependence (Table 1) and can therefore be used in determining approximate composition of the glass.

**Table 1.** Selected Raman bands\* of An-Ab glasses.

Sample	$\nu_s(\text{T-O-T})$	$\nu_{as}(\text{T-O-T})$ doublet	
An <sub>100</sub>	504 s**	960 m	1034 sh
An <sub>75</sub>	495 s	957 m	1042 sh
An <sub>61</sub>	487 s	963 m	1054 sh
An <sub>50</sub>	476 s	981 m	1079 sh
An <sub>31</sub>	472 s	981 m	1084 sh

\*in  $\text{cm}^{-1}$ ; \*\* sh, shoulder; s, strong; m, medium intensity.

The  $\nu_s(\text{T-O-T})$  and  $\nu_{as}(\text{T-O-T})$  Raman bands are also known to be sensitive indicator of shock amorphization of plagioclase crystals, as well as to shock history of the glasses [9]. These fingerprint Raman bands can be used to estimate the peak shock pressure of the shocked materials on a planetary surface. The telescopic Raman spectra thus have potential to be used for distinguishing between glasses formed by volcanic processes and glasses formed by impact processes. Further work is needed to reduce the mass and power consumption of our prototype telescopic Raman system before it could be used on a lander or rover.

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