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OPTICAL CHARACTERIZATION OF INFRARED TELLURIDE GLASS FIBERS FOR SPACE USE

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ABSTRACT

High Tellurium (Te) content chalcogenide glass fibers are considered as candidates for single mode waveguides in the upper wavelength range (10 – 20 µm) of the DARWIN mission. In this paper two methods for IR optical characterization of the Te glass fibers are presented, including (1) a broadband spectral technique using an FTIR spectrophotometer and (2) a CO_2 laser set-up for measuring the fiber attenuation at 10.6 µm. In both methods the optical attenuation (in dB/m) of experimental mono index Te glass fibers of around 500 µm diameter has been determined by applying the fiber cut-back technique. Some typical results of both methods for a few different types of high Te-glass fibers will be shown.
Since Te-glasses are semiconducting materials, the optical properties of Te-glass fibers strongly depend on temperature. Preliminary low temperature measuring results confirm the beneficial effect of cooling on the transmission of high Te glass fibers.

1. INTRODUCTION

An important measuring technique under study for the DARWIN planet finding mission, is nulling interferometry [1,2]. The main goal of this mission is to identify terrestrial planets, orbiting around nearby stars and capable of having an atmosphere, so possibly supporting life. The principle of nulling interferometry is the destructive interference of the intense light emitted by a central star, thus enabling the detection of the weak infrared emission lines of the orbiting planet. This technique requires a perfect wavefront of the light beams to be combined in the interferometer. By using a single mode waveguide before detection, higher order modes are filtered and a virtually perfect plane wavefront is obtained
Since the main emission lines of the relevant atmospherical components like CO_2, O_3 and water vapour are all in the mid IR, from 4 – 20 µm, the envisaged single mode waveguides must be transparent in this spectral range.
Step index, Te-As-Se (TAS) chalcogenide glass fibers are considered to be suitable waveguides for the lower DARWIN wavelength range from 4 – 10 µm [1,2]. In this paper, high Te content chalcogenide glasses are proposed as candidates for waveguides in the upper (10 - 20 µm) DARWIN wavelength range. Typical results of optical characterization on unclad, mono-index fibers of high Te glass compositions are presented and discussed here.

2. EXPERIMENTAL

2.1 Preparation of unclad high Te glass fibers

Unclad (mono index) high Te content fibers were manufactured from the following chemical glass compositions:

- TeGeGaI
- TeGeI
- TeGeSe

Using special raw materials preparation, chemical purification and glass melting procedures [3], glass rods of about 9 mm diameter and about 10 cm length were manufactured. These glass rods were drawn to mono index fibers (ø from 400 – 550 µm), using a special fiber drawing machine, described previously [4]. Several meters of three TeGeGaI type mono-index fibers (two non-purified ø400 µm and one purified ø400 µm/ø520 µm) were drawn, showing a good surface quality, free of defects or crystallization (see Fig. 1.).

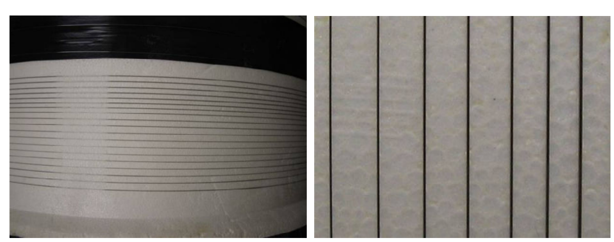

Fig. 1. Mono-index TeGeGaI fiber on drum

Similar preparation procedures were used to manufacture fibers of more than 10 meters length from the TeGeI and TeGeSe glass compositions.

2.2 Infrared optical characterization methods

(1)Broadband spectral set-up

An experimental set-up was built for measuring the spectral loss of the unclad (mono-index) Te glass fibers in the region 4 – 20 µm by the fiber cut-back technique. The components of this set-up are described in Table 1.

Table 1 Components of broadband spectral set-up

Component	Specification
Light source	Ceramic coil, emitting from 1.5 – 55 µm
Detector	MIRTGS (1 – 45 µm) with CsI window
Detection instrument	Perkin Elmer 2000 FTIR spectrophotometer with CsI beamsplitter and CsI window
Fiber holder	Aluminium substrate with V-groove on alignment stage
Optics	Mirrors for focussing the light into the fiber
Pinhole	0.9 mm diameter for defining the focus point at the input of the fiber

Some pictures of the set-up are presented in Fig. 2.

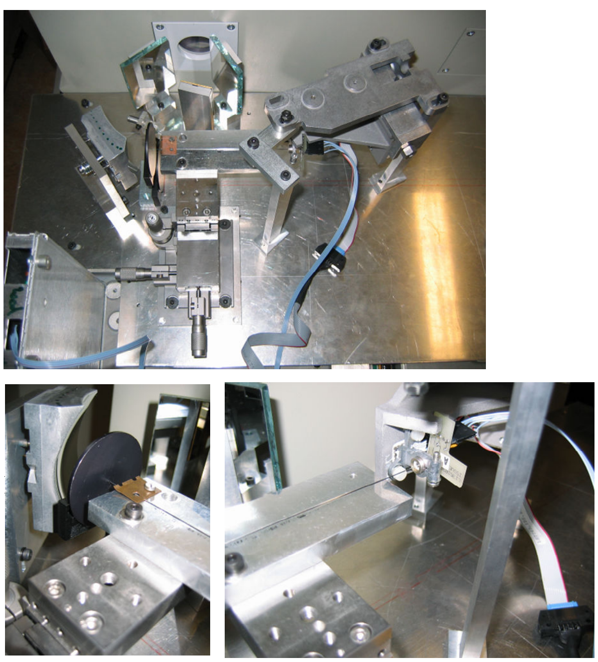

Fig. 2. Top view of broadband spectral set-up (top) with details, showing the fiber (on Al substrate) in front of the pinhole (bottom left) and the output of the fiber close to the detector window (bottom right)

(2) CO_2 laser set-up

The attenuation measurements at 10.6 µm using the cut-back method are performed with a pulsed CO_2 laser (SYNRAD J48-1SW). The maximum output power is 10W, the beam size is about 3 mm and the pulse frequency is 5 kHz. The output optical power can be tuned by changing the duty cycle. The set-up is sketched in Fig. 3.

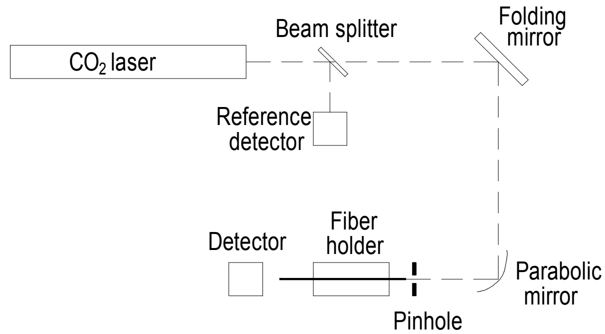

Fig. 3. Pulsed CO_2 laser set-up for fiber attenuation measurements at 10.6 µm

3. RESULTS OF OPTICAL ATTENUATION MEASUREMENTS ON TE-GLASS FIBERS

3.1 Attenuation at room temperature

Spectral attenuation of TeGeGaI fibers

The transmission of two TeGeGaI fiber samples, approximately 5 cm long, was measured using the broadband spectral set-up. One fiber sample was prepared from an untreated glass and another sample from a similar glass composition, after an additional chemical purification procedure to remove (oxygen) impurities.

The corresponding spectra are presented in Fig. 4.

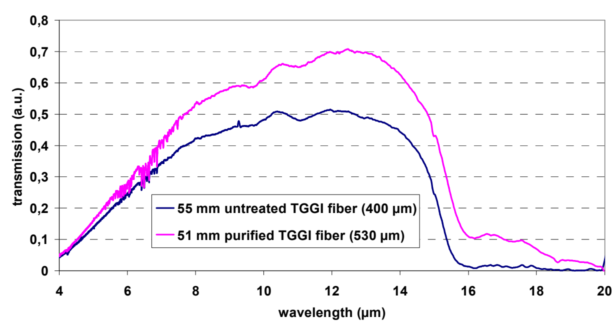

Fig. 4. Comparison of spectral transmission of a 5 cm fiber of purified and non-purified (untreated) TeGeGaI mono-index fiber

It can be seen in Fig. 4 that the TeGeGaI fiber has the highest transmission in the 12 – 13 µm region. Besides, part of the absorption of the TeGeGaI fiber in the region 15 – 20 µm is extrinsic, probably due to oxygen related impurities. By the application of proper

purification methods, the transmission in the region 15 – 20 µm can be increased.
Next, the spectral attenuation of a 9 cm long sample of the purified TeGeGaI fiber was determined by cutting back this fiber piece in 3 steps to about 3 cm.
The measured average spectral attenuation is presented in Fig. 5.

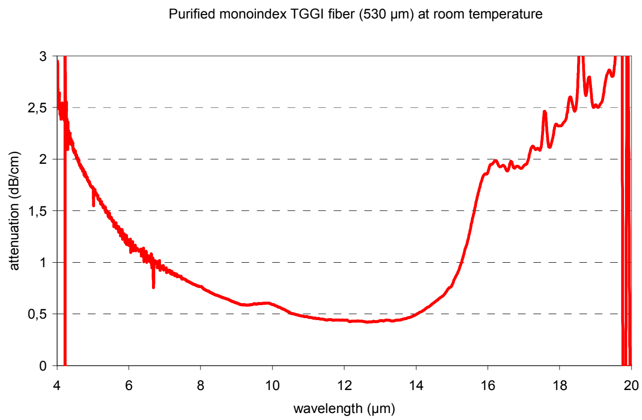

Fig. 5. Averaged spectral attenuation (dB/cm) of a purified TeGeGaI fiber at room temperature determined by fiber cut-back method

A minimum in the attenuation of 0.4 dB/cm was found between 12 and 13 µm. The attenuation between 16 and 20 µm increases from a value around 1.5 dB/cm to 3 dB/cm.

Although the measured values for the spectral loss are still relatively high, these results prove that the purified TeGeGaI fiber transmits light in the region between 15 and 20 µm through short fiber samples. This performance can probably be improved by advanced glass manufacturing processing and improved purification methods.

Attenuation of high Te fibers at 10.6 µm
The attenuation at 10.6 µm of fiber samples of about 50 cm long of the glass types TeGeGaI, TeGeI and TeGeSe was determined by cutting back these fibers in many steps to about 10 cm. After each cut the transmitted light intensity through the remaining fiber length was measured.
The results of the fiber cut-back measurements with the CO_2 laser set-up are summarized in Table 2.

Table 2 Attenuation at 10.6 µm of different high Te-glass fiber types (unclad), made from purified glasses

Fiber type	Attenuation (dB/cm)
TeGeGaI	0.46
TeGeI	0.17
TeGeSe	0.10

The measured loss value at 10.6 µm of 0.46 dB/cm for the TeGeGaI glass fiber corresponds reasonably well with the measured values between 10 and 11 µm in Fig. 5. Apparently, the optical loss at the CO_2 laser wavelength (10.6 µm) of the glass fiber types TeGeI and particularly TeGeSe is considerably lower.
This observation was confirmed by other spectral measurements, not reported here, which showed that the TeGeSe glass fibers have a minimum attenuation between 10 and 11 µm, so slightly shifted to shorter wavelengths compared to TeGeGaI fibers. The origin of the differences in the optical loss between the different fiber types (intrinsic/extrinsic absorptions, glass quality, crystals in the fiber, etc.) is still under study.

3.2 Attenuation at low temperatures

In order to simulate temperature conditions in space, a qualitative experiment was carried out on a 135 mm long TeGeGaI-fiber, cooled by liquid N_2, using the broadband FTIR set-up of Fig. 2.. The spectrum measured at low temperature was compared to the spectrum of the same fiber at room temperature and the ratio of both curves was calculated, as shown in Fig. 6.

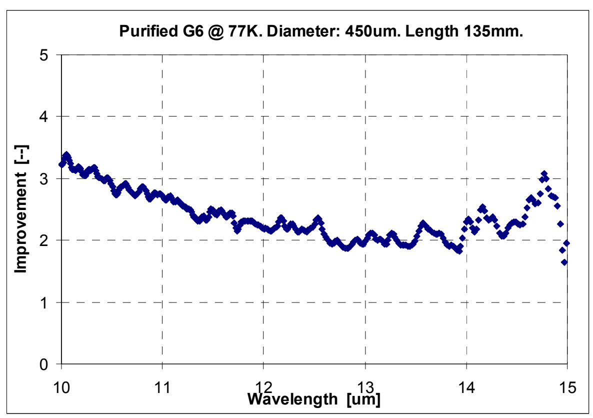

Fig. 6. Factor of improvement in transmission of a TeGeGaI fiber at liquid nitrogen compared to room temperature

It can be seen in Fig. 6 that the transmission of the TeGeGaI fiber increases at low temperature and that the improvement due to cooling is wavelength dependent. The minimum improvement in optical transmission at liquid N_2 temperature is a factor of 2 at about 13 µm.

4. CONCLUDING REMARKS

The optical loss of different types of high Te content, unclad glass fibers was measured by the fiber cut-back method, using a broadband FTIR set-up and a single wavelength CO_2 laser set-up. Optical attenuation values down to 0.1 – 0.5 dB/cm were measured, depending on glass type, glass preparation/purification processes and IR wavelength. The TeGeSe glass fiber samples appeared to have the lowest loss of 0.1 dB/cm at 10.6 µm.

Since high Te-glasses are semiconducting materials, the optical properties of Te-glass fibers strongly depend on temperature. Preliminary low temperature measurements showed an improvement of the Te glass fiber transmission at liquid nitrogen temperatures of minimum a factor 2.

Taking into account the optical transmission results, it is concluded that high Te-glass fibers are realistic candidates for satisfying the DARWIN waveguide requirements in the upper wavelength range from 10 – 20 µm.

5. REFERENCES

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