

LETTERS

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IR luminescence of tellurium-doped silica-based optical fibre

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Abstract. **Tellurium-doped germanosilicate fibre has been fabricated by the MCVD process. In contrast to Te-containing glasses studied earlier, it has a broad luminescence band (full width at half maximum of ~350 nm) centred at 1500 nm, with a lifetime of ~2 μs. The luminescence of the fibre has been studied before and after gamma irradiation in a ^{60}Co source to 309 and 992 kGy. The irradiation produced a luminescence band around 1100 nm, with a full width at half maximum of ~400 nm and lifetime of ~5 μs.**

Keywords: *tellurium, tellurium-doped optical fibre.*

The ever increasing amount of information transmitted through optical fibre communication lines (30% to 40% per year) requires a drastic increase in their data rate. Currently, the per-fibre capacity in commercial communication networks is 10 Tbit s^{-1}. Such systems employ the narrow spectral range 1530–1610 nm, defined by the gain band of erbium-doped fibre amplifiers. One way to sharply increase the transmission capacity of optical fibre communication systems is to use the entire spectral region (1300–1700 nm) where telecom silica fibres have low losses (under 0.4 dB km^{-1}). This, however, requires the development of efficient optical amplifiers for this spectral region.

As shown more than a decade ago [1, 2], bismuth-doped silica glass luminesces in the range 1000–1600 nm. In 2005, such glass was used to fabricate optical fibres, which were demonstrated to lase [3]. Subsequently, lasing was achieved in a wide spectral range (1150–1550 nm) [4], and a fibre amplifier for wavelengths around 1430 nm was designed [5]. The structure of the bismuth-related luminescence centre remains, however, unclear, which prevents optimisation of bismuth-doped fibres.

The study of the optical properties of glasses and fibres doped with p-elements that are neighbours of bismuth in the periodic table and have a similar electronic configuration in certain charge states may, on the one hand, shed light on the structure of the bismuth-related active centre and, on the other, help to find active media with new properties of practical interest.

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In particular, the luminescence properties of germanate glasses doped with a number of post-transition elements (Bi, Pb, Sb, Sn, Te and In) were studied by Sharonov et al. [6] using excitation in the visible range. According to their results, Bi, Pb, Sb and Sn form optical centres that are very similar in the position (1100–1200 nm) and shape of their near-IR luminescence band. In the case of Bi and Pb, luminescence was observed no matter whether the glass had been prepared in air or a nitrogen atmosphere. The Sb- and Sn-doped glasses showed luminescence only when prepared in a nitrogen atmosphere, i.e. under reducing conditions. In the case of In and Te doping, there was no near-IR luminescence. Also, no near-IR luminescence was detected in tellurium-doped borate glasses [7].

At the same time, according to luminescence studies of tellurium-doped soda–lime–silica glasses [8, 9], additional doping of such glasses with carbon (which also creates reducing conditions) may lead to luminescence at 1200 nm under excitation at 974 nm.

It is worth noting that reducing conditions can be ensured not only by an oxygen-deficient atmosphere and carbon doping but also by X-ray or gamma irradiation.

In this paper, we report the luminescence properties of a Te-doped germanosilicate fibre and their response to high radiation doses. We used a multimode fibre fabricated by MCVD, with the core composition Te:94SiO_2–6GeO_2. Tellurium was introduced by the solution doping technique, and the porous layer was sintered in an oxygen atmosphere. The Te concentration was below the detection limit of our analytical facilities (0.02 at%). The drawing process was run at 2000 °C.

The optical loss was measured using a standard technique: by comparing the transmission of different lengths of the fibre. In luminescence measurements, excitation was provided by laser diodes (808, 975, and 1240 nm) and an ytterbium fibre laser (1058 nm). Luminescence spectra were obtained on an Ocean Optics QE6500 spectrometer in the visible range and on an Ocean Optics NIRQuest512 spectrometer in the near IR. To rule out the influence of reabsorption, the luminescence signal was collected from the cladding as described elsewhere [10]. The data were corrected for the spectral response of the measuring system. The luminescence lifetime was measured with a Thorlabs PDA10CS amplified InGaAs photodetector. Its signal was fed to a LeCroy WavePro 7100 oscilloscope.

Fibre samples were irradiated in a ^{60}Co gamma source to doses of about 309 and 992 kGy.

The optical loss spectrum of the unirradiated fibre is presented in Fig. 1. The spectrum contains an absorption band around 430 nm (~850 dB m^{-1}), a composite shoulder in the range 520–670 nm (~200 dB m^{-1}), a band near 850 nm (~5 dB m^{-1})

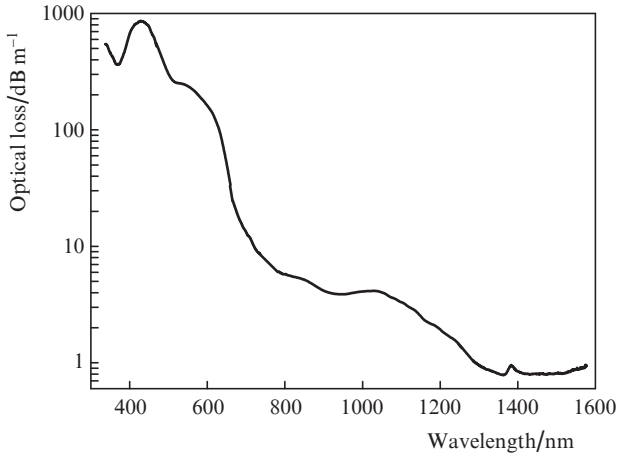

Figure 1. Optical loss spectrum of the tellurium-doped germanosilicate fibre.

and a composite band between 950 and 1300 nm (~4 dB m^{-1}). There is also a small feature at 1380 nm, which seems to arise from OH groups.

The luminescence spectra of the unirradiated fibre at different excitation wavelengths are presented in Fig. 2. When pumped at 975, 1058 or 1240 nm, the fibre had a broad luminescence band centred around 1500 nm, with a shape essentially independent of the excitation wavelength. The luminescence lifetime under these conditions was however not very long, approximately 2 μs.

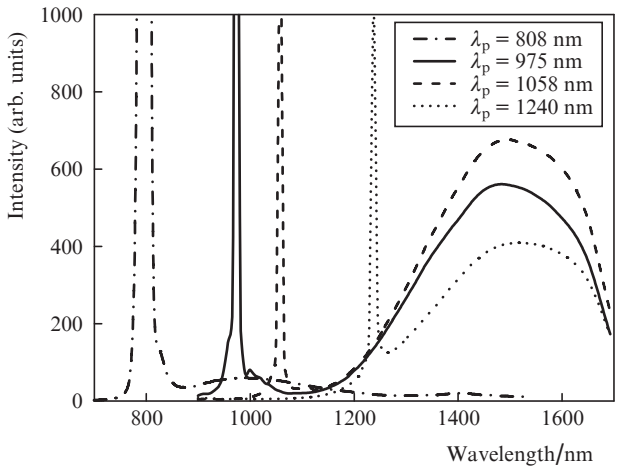

Figure 2. Luminescence spectra of the tellurium-doped germanosilicate fibre at different excitation wavelengths (λ_p).

Figure 3 shows the luminescence spectra of the unirradiated tellurium-doped germanosilicate fibre and the samples gamma-irradiated to different doses (excitation wavelength, 808 nm). The unirradiated fibre had two relatively weak emission bands around 1000 and 1400 nm. The irradiation produced a stronger band around 1100 nm, with a luminescence lifetime of ~5 μs.

The luminescence spectra of the same samples under pumping at 975 nm are presented in Fig. 4. The spectrum of the irradiated fibre is very broad, 1000–1650 nm, extending over almost the entire near-IR spectral region. The luminescence lifetime is ~2 μs, like in the unirradiated fibre. The complex

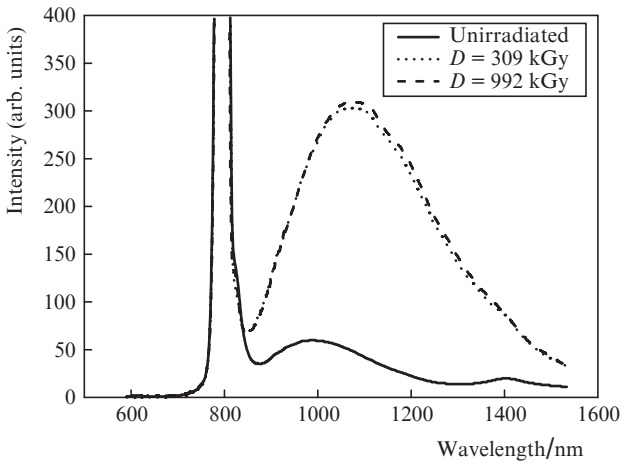

Figure 3. Luminescence spectra of the tellurium-doped germanosilicate fibre before and after gamma irradiation to different doses (D). Excitation wavelength, 808 nm.

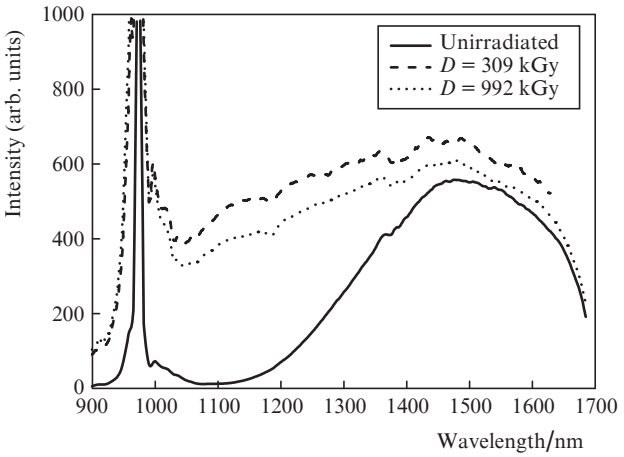

Figure 4. Luminescence spectra of the tellurium-doped germanosilicate fibre before and after gamma irradiation to different doses (D). Excitation wavelength, 975 nm.

structure of the luminescence spectrum after the irradiation can be accounted for, at least in part, by the insufficiently accurate normalisation, as a result of which the absorption band of OH groups appears at 1380 nm, and that of the polymer coating of the fibre, at 1180 nm.

When comparing the present results to earlier data, it is worth noting that previous work addressed the luminescence properties of tellurium-doped glasses with a significantly different composition. An even more important point is that, at a given glass composition, fibres may differ in luminescence properties from bulk glass [4]. The reason for this is that bulk glasses and optical fibres are produced under different conditions, primarily at different temperatures and vapour phase compositions, which determine the reduction of the active element and, as a consequence, its charge state. These factors can explain why, in our experiments, the tellurium-doped silica-based fibres showed IR luminescence at 1500 nm, whereas tellurium-doped bulk glasses luminesce at 1100 nm [8, 9].

Thus, we have fabricated the first tellurium-doped optical fibre. Under excitation at wavelengths from 975 to 1240 nm, it exhibits broadband luminescence centred at ~1500 nm, with a full width at half maximum $\Delta\lambda \approx 350$ nm and lifetime $\tau \approx 2$ μs.

We have studied the effect of gamma irradiation on the luminescence properties of the fibre. Exposure to a gamma dose of 309 kGy or above produces a luminescence band with λ_{max} = 1100 nm, $\Delta\lambda \approx 400$ nm and $\tau \approx 5$ μs.

The present results demonstrate that tellurium-doped optical fibres can be used as active laser materials for the spectral region 1300–1600 nm.

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References

1. Murata K., Fujimoto Y., Kanabe T., Fujita H., Nakatsuka M. *Fusion Eng. Des.*, **44**, 437 (1999).
2. Fujimoto Y., Nakatsuka M. *Jpn. J. Appl. Phys.*, **40**, L279 (2001).
3. Dianov E.M., Dvoyrin V.V., Mashinskii V.M., Umnikov A.A., Yashkov M.V., Gur'yanov A.N. *Kvantovaya Elektron.*, **35**, 1083 (2005) [*Quantum Electron.*, **35**, 1083 (2005)].
4. Bufetov I.A., Dianov E.M. *Laser Phys. Lett.*, **6**, 487 (2009).
5. Melkumov M.A., Bufetov I.A., Shubin A.V., Firstov S.V., Khopin V.F., Guryanov A.N., Dianov E.M. *Opt. Lett.*, **36**, 2408 (2011).
6. Sharonov M.Yu., Bykov A.B., Petricevich V., Alfano R.R. *Opt. Lett.*, **33**, 2131 (2008).
7. Khonthon S., Punpai P., Morimoto S., Arai Y., Suzuki T., Ohishi Y. *J. Ceram. Soc. Jpn.*, **116**, 829 (2008).
8. Khonthon S., Morimoto S., Arai Y., Ohishi Y. *J. Ceram. Soc. Jpn.*, **115**, 259 (2007).
9. Punpai P., Morimoto S., Khonthon S., Arai Y., Suzuki T., Ohishi Y. *J. Non-Cryst. Solids*, **354**, 5529 (2008).
10. Mattsson K.E. *Opt. Express*, **19**, 19797 (2011).