Silica based optical fibres with "exotic" dopants: toward new applications in amplification of optical signal and sensing

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Abstract

Since the first demonstration of the Erbium Doped Fibre Amplifiers (EDFA) for the amplification of optical signal without opto-electronic devices in 1987 (1), this technology enabled the development of wavelength-division multiplexing over the C and L-bands (1530-1625 nm) and has accompanied the rise of fibre optic networks, which are now at the heart of the Internet traffic worldwide. However, the development of new generations of mobile networks (4G, 5G) combined with services requiring ever-increasing data exchanges is straining the fibre optic network to an unprecedented level. This provokes the saturation of the traditional bands and requires the opening of new spectral channels (ex. O and E-band between 1260 and 1460 nm) as well as suitable optical amplifiers. Therefore, the development of new optical fibre dopants that provide optical gain in these spectral regions remains an active research topic. Moreover, new applications for optical fibres require the access to novel active fibres for temperature and pressure sensing and dosimetry. These requirements enlarge the scope of possible dopants to novel active ions such as cerium, gadolinium or bismuth.

First part of this presentation reports on the elaboration and characterisation of bismuth doped optical fibres. Indeed, this post-transition metal reveals interesting properties when inserted in the silica matrix. More precisely, it turns out that Bismuth Active Centres (BAC) exhibit absorption and luminescence bands whose position is very sensitive to the co-dopant present in the silica glass, and that bismuth can change its oxidation state as a function of the atmosphere applied during the fabrication of the preform. In our research, we focus on bismuth-doped fibre amplifiers (BDFA) based on phosphosilicate core composition exhibiting absorption around 1300 nm and hence inscribed into the O-band. In order to achieve this goal, we have investigated different glass manufacturing techniques, starting from the sol-gel synthesis and post-doping with the cations of Bi3+ (2), going through Outside Vapor Deposition (OVD) with the soaking of soot and isostatic pressurisation, concluding with Modified Chemical Vapor Deposition (MCVD) coupled with solution doping technique. These assays conducted to Bi-doped glass preforms with the level of BAC permitting to observe absorption and optical gain in the O-band.

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In the second part, the elaboration of new active fibres based on cerium or cerium/gadolinium co-dopants will be discussed. Ce3+ cations reveal very interesting spectroscopic properties in the visible region once exposed to the ionizing radiation. However, this ion can oxidize easily in silica glasses and therefore, the control of its oxidation state and the application of reducing agents during the glass fabrication is mandatory. In our studies, we have manufactured by MCVD different silica glass preforms doped with cerium cations and then performed thermal treatment with oxidizing, inert and reducing atmosphere to enhance the formation of Ce(III) in silica. These assays conducted us to Ce-doped silica fibres showing large emission peak around 450 nm after the radiation of X-rays. The dosimetry measurements with dose-rate range from few μGy(SiO2)/s up to hundreds of Gy(SiO2)/s revealed the linear response of the radioluminescence of these fibres versus the X-ray dose and the important accumulated dose (3). Moreover, these fibres were investigated by thermoluminescence technique.

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