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Extended Abstract

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Advances in infrared optical fibers

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Infrared fibers offer a versatile approach to guiding and manipulating light in the infrared spectrum, which is becoming increasingly more prominent in a variety of scientific disciplines and technological applications. Despite well-established efforts on the fabrication of infrared fibers over the past decades, a number of remarkable breakthroughs have recently rejuvenated the field ? just as related areas in infrared optical technology are reaching maturation. In this review, we describe both the history and recent developments in the design and fabrication of infrared fibers including infrared glass and singlecrystal fibers, multimaterial fibers, and fibers that exploit the transparency window of traditional crystalline semiconductors. This interdisciplinary review will be of interest to researchers in optics and photonics, materials science, and electrical engineering.

The polycrystalline silver halide optical fibers, either of square cross section (750 × 750 μm2) or of circular cross section with a diameter of 700 μm, were supplied from infrared fiber sensors (Aachen, Germany). In Fig. 3.1 the surfaces of these two types have been characterized by scanning electron microscopy (SEM) at two different enlargements. Other fibers were purchased from ArtPhotonics (Berlin) and CeramOptec (Bonn). We also acknowledge the collaboration with Professor Katzir from Tel Aviv University (see also Table 3.1). Short fiber pieces were measured by a SEM-EDX JEOL JSM 6400 apparatus from JEOL USA, Inc. (Peabody, MA, the United States). Surfaces due to the extrusion process are very smooth, and at the highest magnification the polycrystalline structure of the material is visible. Despite the fiber flexibility, a maximum radius for multiple bendings must be observed. Smaller radii are possible, but such a bending is irreversible; for further details, see Ref. [33]. These precautions are necessary, when special geometrical arrangements are needed for probe construction.
Synthetic fibers for general use cannot meet the requirements of commercial values. Modified fibers with functional properties, such as antibacterial fibers, UV-protection fibers, flame-retardant (FR) fibers, antistatistic fibers, and far infrared fibers are produced. Two methods are used for their preparation: one is to change the shape of the fiber cross section or the fiber surface morphology, and the other is to add functional additives into the polymer matrix during the spinning process or the finishing process. Not all the functional properties can be easily achieved from the above-mentioned two methods. Other polymers, including aromatic polyamide, aromatic polyester, liquid crystal polymer, polyimide, polytetrafluoroethylene, polysulfonamide, polyphenylene sulfide (PPS), polybenzoxazole, carbon fiber (CF), and polyether ether ketone, are introduced with the features of high tenacity, high modulus, high heat resistance, and excellent flame retardation.

For packaging the fiber cables which are essential for remote sensing applications, a stiff, but still flexible, black polyether ether ketone (PEEK) tubing was used to provide protection from mechanical and chemical damage. Flexible metal tubes can be used alternatively. Titanium-SMA connectors or customer-designed connectors have also been realized.
The dynamics of intracavity Raman lasers can be very complex, since there are multiple optical processes occurring within the resonator. Strong thermal lensing in the laser crystal (Innocenzi et al., 1990) frequently limits the power and beam quality available from diode-pumped crystalline lasers, including intracavity Raman lasers. In the case of Raman lasers thermal lensing in the Raman crystal due to Raman heating can be an issue too. As we have shown previously (Pask, 2003) the thermal load in the Raman crystal is proportional to the average first Stokes power. Accordingly thermal properties as well as nonlinear properties of Raman crystals must be taken into account when selecting the Raman crystal for an intracavity laser. Many combinations of laser and Raman crystals have been reported, including self-Raman lasers, in which a Raman-active laser crystal performs the dual functions of generating the fundamental and the first Stokes fields. Nd:YVO4, Nd:GdVO4 and Nd:KGd(WO)4)2 have all been used successfully.

The design of the laser resonator is very important in optimising the performance of the intracavity Raman laser. Once the thermal characteristics of the laser and Raman crystals are known, the resonator layout, cavity length, mirror curvatures and output coupling can be chosen so as to optimise the optical mode sizes in the crystals. Optimal spot sizes enable efficient extraction of energy from the laser gain crystal and efficient frequency conversion via SRS to occur simultaneously. In a simple intracavity Raman laser the fundamental and Stokes fields oscillate within the same resonator. Coupled-resonator configurations can also be used where the fundamental and Stokes fields exist in separate resonators that overlap in the Raman crystal. Other design choices include the pump source for the fundamental laser, e.g. diode, arclamp or flashlamp, the pumping geometry, e.g. end-pumped or side-pumped, and whether the laser is pulsed or CW. In the case of pulsed operation, acousto-optic, electro-optic and passive Q-switching have all been used successfully.

Bottom Note: *This work is partly presented at International Conference and Trade fair on Laser Technology, July 20-22, 2015, Orlando, Florida, USA*