

REDUCED GRAVITY ZBLAN OPTICAL FIBER

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Abstract

Two optical fiber pullers have been designed for pulling ZBLAN optical fiber in reduced gravity. One fiber puller was designed, built and flown on board NASA's KC135 reduced gravity aircraft. A second fiber puller has been designed for use on board the International Space Station.

Introduction

Mid infrared fiber optics have many promising applications. These include high capacity wavelength multiplexed fiber optic devices, remoting of infrared focal planes, infrared laser devices, long-length fiber optic sensor systems and nonlinear optical systems. Heavy metal fluoride glasses have shown the most promise to date. The most stable heavy metal fluoride with respect to crystallization appears to be those in the ZrF_4 - BaF_2 - LaF_3 - AlF_3 - NaF family, commonly known as "ZBLAN" glasses.²

Intrinsic and extrinsic processes limit light propagation at low powers in ZBLAN.³ Intrinsic properties include band gap absorption, Rayleigh scatter and multiphonon absorption. Extrinsic processes include impurities such as rare earth and transition metal ions and crystallites formed during preform processing and fiber pulling. The theoretical loss coefficient for ZBLAN is 0.002 dB/km at 2 microns. Achieving this lower limit is hampered by both intrinsic and extrinsic processes.

All of the intrinsic processes and extrinsic impurities can be controlled through processing of the initial raw materials and in preparation of the glass preform. The devitrification of ZBLAN is due to a narrow working range and low viscosity at the pulling temperature.⁴ These two factors make this glass unstable and prone to crystallization. Microgravity processing offers the potential to

minimize these losses in ZBLAN glasses.⁵ It also offers the potential of minimizing phase separation and crystallization during glass forming steps.⁵ Fluoride glass synthesis has not been attempted in microgravity to date due to the corrosive nature of the process.⁵

Canadian work indicated the enhanced crystallization of certain ZBLAN formulations under 2g and no evidence of crystallization in 0g using a T-33 aircraft.^{5,6} Research by the authors of this paper found similar results.⁷ It is felt by the authors that an approach of processing preforms in microgravity to get rid of crystallites followed by microgravity fiber pulling will afford optimum optical fiber. This paper describes fiber pulling of ZBLAN.

Experimental and Results

To try and understand the nuances of pulling fiber in reduced gravity a fiber pulling apparatus (FPA) was designed and built for use on NASA's KC135 microgravity aircraft. A schematic of this apparatus is shown in Figure 1. In operation, a preform is located at the top of the apparatus. A platinum sting is fed from the take-up reel to the bottom of the preform. The preform tip is heated to just below the glass transition temperature, the sting touches the tip and fiber is drawn downward onto the take-up reel. During the drawing operation, the fiber passes through a polymer coater where a thin layer of polymer is applied to the fiber surface and is subsequently cured by UV radiation. The polymer coating serves to protect the fiber from surface scratches and dirt which would lower fiber strength. The preform is fed by a motor which insures a continuous supply of glass for drawing.

Preform feed rate, pulling rate and preform temperature are controlled by computer in which data is also continuously stored. The components are housed in a plexiglass and aluminum container which rests on an aluminum frame bolted to the aircraft floor. Dry nitrogen is fed into the housing to reduce relative humidity. A hygrometer attached to the housing indicates relative humidity. ZBLAN preforms prepared by Infrared Fibers Inc.* were pulled in this apparatus on the ground and on board the KC135. Ground samples crystallized rapidly during fiber pulling. On-board the KC135 the samples did not crystallize until the 2g portion of the parabola was entered. Then the fluid jet zone at the preform tip was observed to crystallize rapidly turning a transparent white. At this point the fiber would break at the preform tip. This phenomena occurred during each 2g portion of the parabola making continuous fiber pulling an impossibility. The fluid jet zone was also observed to change shape drastically during the transitions from low-g to 2g.

A fiber pulling apparatus has also been designed for use on board the International Space Station. This apparatus is designed to fit into an express rack and is shown in Figure 2. This apparatus is completely enclosed and will be operated using a laptop computer. A joystick will control insertion of the sting into the preform tip.

Discussion

It appears qualitatively, that gravity does have an effect on ZBLAN crystallization during fiber pulling. The exact mechanism is unknown at this time.

Before building the Space Station fiber puller, a scaled down glove box fiber puller will be constructed to test the feasibility of pulling in microgravity. In this experiment, a preform will be placed at one end of the glovebox with a take-up reel at the other end. Using a quartz rod, an astronaut will pull the heated tip into a fiber and attach it to the take-up reel. The fiber will then be drawn. By adjusting the viscosity of the fiber and the draw speed the diameter can be controlled. A thin coating of polymer will be applied to the fiber. Attenuation coefficients will be measured. If the attenuation coefficients are tending toward near theoretical (0.002 dB/km) then production of ZBLAN optical fiber will proceed using the apparatus in figure 2.

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