Electrically tunable Brillouin fiber laser

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Abstract: We report temperature characteristics of the Brillouin lasing achieved in optical fibers coated by metals. The Brillouin laser tunability within the range of 25 MHz is demonstrated by applying of direct voltage to the metal coating.

Fiber lasers based on stimulated Brillouin scattering (SBS) are of great interest for many applications in telecommunication and sensing [1-3]. Here we report a ring Brillouin fiber laser built from a metal-coated optical fibers. The main advantage of such fibers is that they can operate at high temperatures (up to 950^{0}C) [4-5] and high pressures (up to 14 GPa) making the reported laser configuration attractive, in particular, for sensor applications in energy, metallurgy, geophysics, oil-industry, etc. The temperature dependences of the Brillouin frequency shift in such fibers are reported here for the first time.

The experimental configuration of the Brillouin fiber laser is shown in Fig.1. The configuration is pumped with the maximal output power of 150 mW at 1550nm from a 100kHz laser diode amplified by an erbium doped fiber amplifier (EDFA). The Brillouin fiber cavity includes an optical circulator and 11 m of the metal-coated fiber. An optical 95/5 coupler is used to extract the light at pump (Out 1) and Brillouin (Out 2) frequencies from the cavity. A polarization controller adjusts the light polarization state inside the cavity. The Brillouin frequency shift is measured by recording of radio-frequency spectrum (HP70000) of the beat signal combining Out 1 and Out 2 signals.

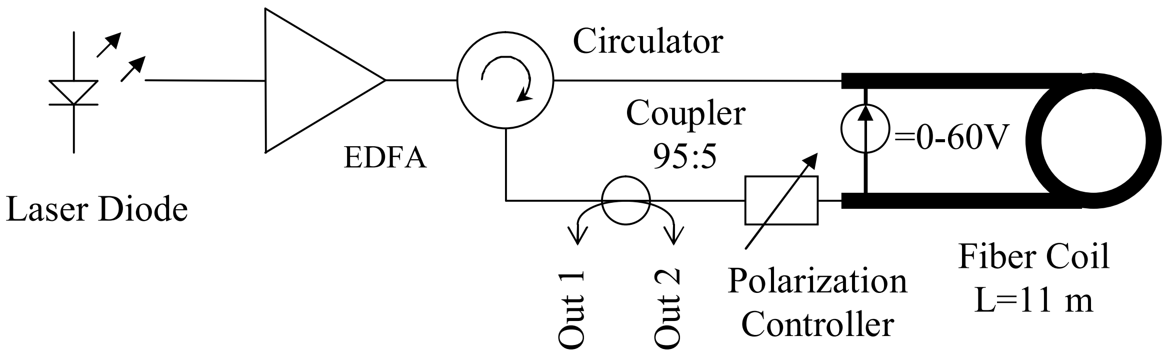

Fig. 1. Scheme of experimental setup

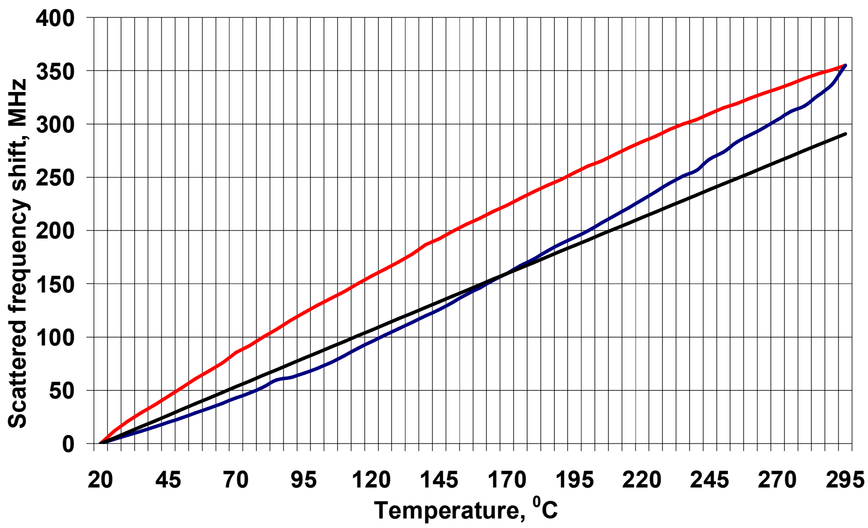

Fig. 2. Dependence of Brillouin frequency shift on the temperature (red – heating, blue – cooling, **black** – curve for Corning SMF-28)

We used single-mode optical fibers with copper alloy coating manufactured by IRE RAS as experimental samples. The Brillouin laser configuration built from the metal coated fiber was heated in the oven to the temperature of 300^0C during 3 hours and then during 3 hours cooled down to 20^0C. Besides, a tunability of the laser within the range of 25MHz was demonstrated by passing of electric current directly through the metal fiber coating.

The temperature dependence the Brillouin frequency shift is shown in Fig. 2. The measured Brillouin shift at room temperature (20 ^{0}C) is 10802 MHz. The figure shows that the curves corresponding to heating and cooling of the fiber are slightly different. It is explained by an enhanced heating capacity of the oven. The average temperature coefficient for the Brillouin frequency shift is estimated as ~1.3 MHz/K. It is higher than the reported previously values (1.05-1.1 MHz/K at $\lambda = 1550$ nm) for Corning SMF-28 fibers. We suppose that such high thermal coefficient is due to additional mechanical stress induced by metal coating that has higher thermal expansion than a silica glass. This result it is important for high-sensitive fiber optical wide-temperature sensors.

Fig.3 demonstrates tunability of the Brillouin laser as its heating is performed by passing an electric current directly through the metal coating leading to the Brillouin frequency shift. Maximum current is 0.5A.

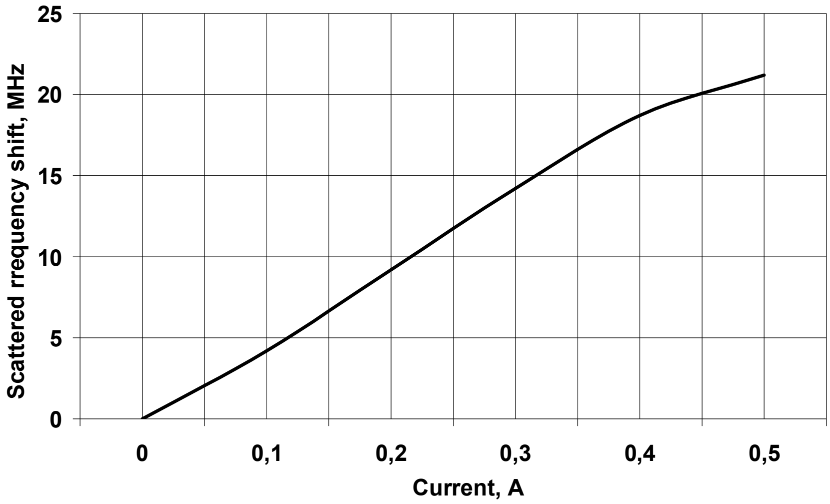

Fig. 3. Brillouin frequency shift vs an electrical current

Above this value the laser generation has not been observed due to extra broadening of the Brillouin spectrum caused by non-uniform heating of the fiber by the current. A typical fiber laser response on the current change of 0.5A is 1 second.

In conclusion, the temperature dependences of the Brillouin frequency shift in metal-coated fibers shows their perfect suitability for Brillouin sensing applications. Tunable Brillouin laser employing direct current heating through the metal coating is also demonstrated. This work was supported by the European FP7 IRSES project, the European Regional Development Fund and the Walloon Region (Mediatic project), the Interuniversity Attraction Pole program IAP PVII-35 of the Belgian Science Policy, program “Scientific and Research-Educational Cadres for Innovation Russia” of Ministry of Education and Science of the Russian Federation.

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