Whispering gallery modes on the surface of an optical fiber reflecting from its end

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Whispering gallery modes (WGMs) excited on the surface of cylindrical fiber microcavities, and in particular on the surface of an optical fiber, can have a nonzero propagation velocity along the cavity axis, which depends on the variation of the effective radius [1]. The speed of propagation of modes can be controlled by varying the radius of the fiber. Also, the mode propagation speed depends on the difference between the resonant wavelength of the microcavity and the wavelength at which the mode propagates [2]. On the basis of such resonators, devices can be created for generating optical combs, delay lines, optomechanical switches, etc.

An actual task is to find new ways of controlling the axial propagation of modes. One such method would be to use fiber geometry such as a fiber end. When radiation in the whispering gallery mode is incident on the fiber end, the angle between the direction of propagation of the axial WGM and the cleave interface is small (in the ray approximation). Since the refractive index of the silica cladding of the optical fiber is higher than the refractive index of air, total internal reflection can occur at the fiber end. In our work, we studied this WGM reflection process and determined the reflection coefficient.

For this purpose, laser pulses of 0.5 ns duration with wavelengths close to the resonant wavelength with zero axial wave vector were launched into the microcavity made of standard optical fiber. The microcavity end was made by cleaving the fiber with a diamond knife. Radiation was introduced into the resonator through a tapered microfiber. The taper waist is perpendicular to the microcavity. A second taper was used for scanning along the axis of the resonator to probe space-time dynamics of the radiation intensity $I(z, t)$.

Under pulsed excitation, the original wave packet is divided into several pulses propagating along the cladding with different group velocities: in Fig. 1a, at least two separate pulses can be distinguished: the first has such a high group velocity that the time resolution of the oscilloscope is insufficient to see its reflection. It seems that this part of the pulse instantly appears everywhere in the resonator. The other part of the excitation propagates with a finite velocity from the exciting taper located at the point $z = -3200$ μm in the direction of the end, and then is reflected from the fiber cleavage at the point $z = 0$ and moves back from the cleavage.

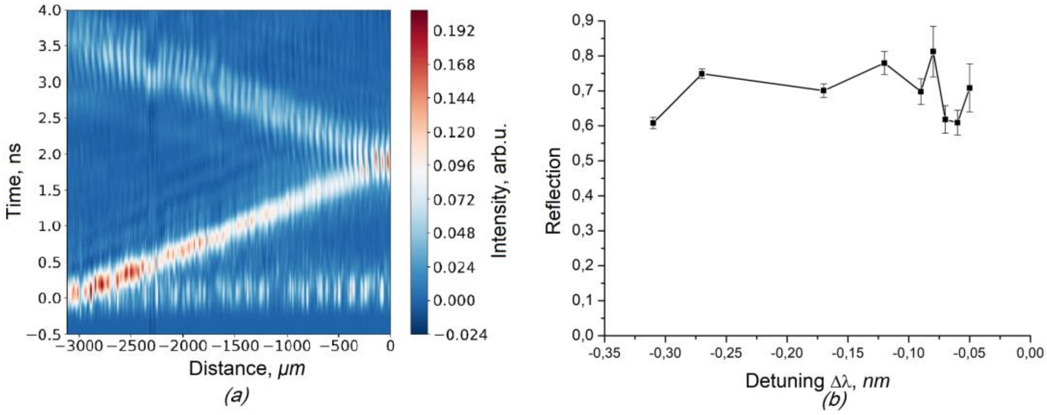

Fig. 1. (a) Spatio-temporal dynamics of a WGM with mode splitting after reflection. (b) Calculated reflection R at the fiber end face as a function of wavelength detuning.

Figure 1b shows a graph of the dependence of the reflection coefficient on $\Delta\lambda$ - the detuning of the pulse wavelength from the resonant wavelength of the mode. The coefficient was calculated as the ratio of the total intensity of the incident and reflected modes. For the sample under study, the reflection coefficient is about 70%. The independence of the reflection coefficient R on $\Delta\lambda$ provides additional information about the reflection process. First, it proves that propagation loss does not affect reflection estimates. Indeed, one might expect that the linear propagation loss should strongly depend on the wavelength - large detunings and large group velocities make the optical path of the mode shorter. This should reduce the net loss and its contribution to the reflectance estimated by our method. Conversely, the independence of the obtained reflectivity from the detuning signals that the effect of losses is negligible. Second, since different $\Delta\lambda$ imply different angles of incidence of the WGM beam to the fiber end, the independence of R on the angle is in good agreement with the assumption that total internal reflection occurs.

The results obtained can be used in devices based on axial WGM resonators to control the properties of modes.

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References

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