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Self-mode locking in a F_2^- : LiF laser by means of a passive switch based on single-wall carbon nanotubes

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***Abstract*. Self-mode locking is achieved in a F_2^- : LiF laser pumped by a cw fibre laser using a new passive switch based on single-wall carbon nanotubes.**

Keywords: *self-mode locking, F_2^- : LiF laser, nanotubes.*

1. The emission wavelength of colour centre F_2^- : LiF lasers at room temperature lies in the range between 1.1 and 1.26 μm [1]. Emission in this wavelength range and its second harmonic are of interest for practical applications. The characteristics of such lasers are described in detail in Refs [1 – 5].

Picosecond and subpicosecond pulses are obtained in F_2^- : LiF lasers by using synchronous pumping (see, for example, [4, 5]). Passive mode locking is such lasers, as far as we know, has not been obtained so far. In this paper, we report self-mode locking in a colour centre F_2^- : LiF laser produced with the help of a passive switch based on single-wall carbon nanotubes (SWNTs).

Passive Q-switching and self-mode locking was obtained earlier [6] in an erbium-doped glass laser by using an SWNT suspension in heavy water. In [6], a review of papers devoted to the study of SWNTs is also presented. Self-mode locking in an Er^{3+}-doped fibre laser achieved with an SWNT-based passive switch was reported in papers [7, 8].

2. The absorption spectrum of an SWNT suspension in heavy water in the region 1 – 1.3 μm is shown in Fig. 1. The arrows indicate the absorption bands corresponding to SWNTs of different types. One can see that the three absorption bands lie within the tuning region of the F_2^- : LiF laser, which can cause nonlinear absorption. As shown in [6], the nonlinear change in the absorption coefficient in the SWNT suspension was 3.6 cm^{-1} for the 1.54-μm radiation with the peak intensity of 40 MW cm^{-2}. The absorption coefficient in a weak filed is $\sim 17\ \mathrm{cm}^{-1}$. The intensity-dependent part of the absorption coefficient was attributed [6] to the absorption of radiation by nanotubes, while the 'background' absorption of $\sim 14\ \mathrm{cm}^{-1}$ was assigned to foreign impurities. One can expect that a nonlinear change in the absorption coefficient in the region 1.1 – 1.2 μm will be similar to that observed at 1.54 μm and that a F_2^- : LiF laser with a SWNT switch can operate in the self-mode locking regime.

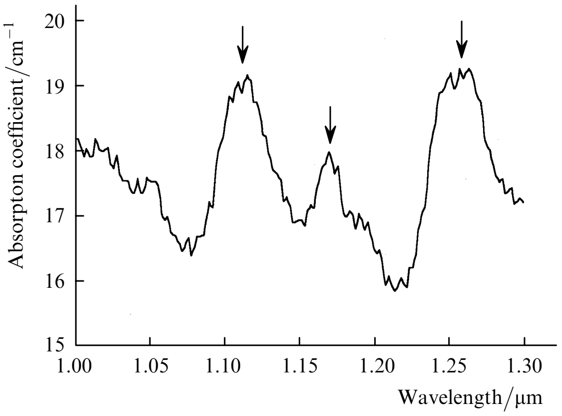

Figure 1. Absorption spectrum of the SWNT suspension in heavy water. The arrows indicate absorption bands corresponding to different types of SWNTs.

The optical scheme of the resonator of a F_2^- : LiF laser is shown in Fig. 2. Cell (*7*) with an SWNT suspension in heavy water was placed near the output mirror. The cell thickness was 8 – 10 μm and the initial transmission at a wavelength of 1.15 μm was $\sim 98\,\%$. The cell windows had antireflection coatings for $\lambda = 1.15$ μm. The laser was pumped at 1064 nm by a diode-pumped cw PYL-1064-20 Yb-doped fibre laser (with the maximum output power of 20 W). The pump radiation was modulated with a shutter to obtain $\sim$ 500-μs pump pulses, the lasing pulse duration being the same. The shutter was used to reduce the thermal load on a passive switch because a significant part of pump radiation (about 50 %) transmitted through an active element was incident on the switch and, reflecting from mirror (*8*), propagated through the cell again. The pump power threshold was exceeded by a factor of 1.5 – 2. A cylindrical LiF active element was rotated around its axis. This design provides cw action of the laser [9, 10]. The output radiation was detected with an LFD 2a photodiode and a Tektronix 7104 oscilloscope with the 0.5 – 1-ns time resolution.

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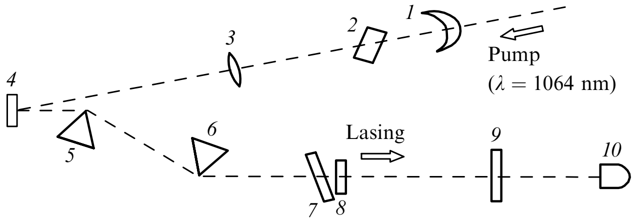

Figure 2. Optical scheme of the passively mode-locked F_2^- : LiF laser: (*1*, *8*) resonator mirrors; (*2*) F_2^- : LiF crystal; (*3*) lens with the 20-cm focal length; (*4*) highly reflecting rotating mirror with the reflectivity ~ 100 % at the pump and lasing wavelengths; (*5*, *6*) group-velocity-dispersion compensator; (*7*) cell with the SWNT suspension in heavy water; (*9*) filters transmitting laser radiation and absorbing pump radiation; (*10*) photodiode.

Figure 3 shows oscillograms of self-mode-locked lasing at different sweep durations. One can see that trains of spikes are observed, the duration of spikes being determined by the time resolution of the detection system. The repetition period of the spikes is equal to the round-trip transit time for radiation in the resonator. The total duration of the pulse train was more than 100 μs.

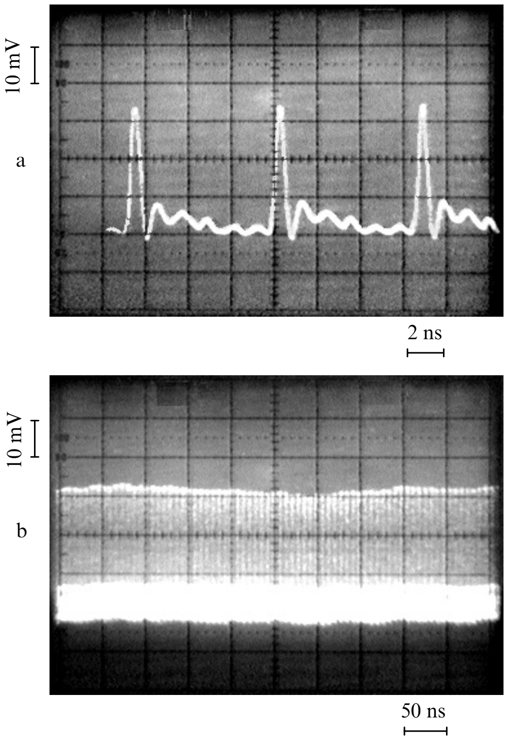

Figure 3. Oscillograms of emission of the F_2^- : LiF laser passively mode locked using a switch based on single-wall carbon nanotubes.

3. Thus, we have obtained self-mode locking in a F_2^- : LiF laser pumped by a cw fibre laser by means of a passive switch based on single-wall carbon nanotubes.

Because the laser design allows cw lasing, by improving the quality of the active element and the cell geometry, we can obtain mode locking in the cw regime. Because the tuning range of F_2^- : LiF lasers is broad, we hope to generate femtosecond pulses is such lasers by means of a passive switch based on single-wall carbon nanotubes.

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