Tunable picosecond pulses from gain-switched grating coupled surface emitting laser.

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ABSTRACT

We have demonstrated a 60 nm-tunable, 160 psec-width, optical pulses from a 980 nm Grating Coupled Surface Emitting Laser (GCSEL) in an external cavity under nanosecond pump pulses. GCSEL is in-plane laser monolithically integrated with grating outcoupler. The grating was detuned from second order Bragg condition and it served as an efficient interface between planar waveguide and free space. Wavelength tuning was simply achieved by tilting an external flat mirror provided wavelength selective feedback to the GCSEL chip. Gain switched pulses with wavelength linewidth less than 0.1 nm and peak power of 200 mW have been obtained. In our experiments we measured a shortest optical pulses by reducing a distance between external mirror and laser diode chip. This corresponded with decreasing the effective laser cavity length and the cavity round-trip time as well.

Keywords: External-cavity lasers, grating couplers, surface emitting laser, wavelength tuning, short pulse generation, semiconductor laser.

1. INTRODUCTION

Widely tunable ultra-short pulse lasers have great importance in all optical communication systems, time-resolved spectroscopy, optical testing and measurements. Especially, a compact tunable picosecond light source, based on the semiconductor laser diode, can play an important role in multiple opto-electronic applications.

Generation of tunable picosecond pulses has been obtained by self-seeding of semiconductor lasers in external cavity[1-4] . In this case a conventional Fabry-Perot laser diode operates in gain-switching regime with weak optical feedback provided by either an external grating[1,2] , or dispersion shifted fiber[3] or combination of two components[4] . At λ=1.3 μm wavelength tuning range up to 40 nm (~3% of the central wavelength) has been obtained from self-seeded lasers with pulse width of about 30 psec [3]. To obtain self-seeding regime one has to pump a laser diode using electrical pulses with high repetition rate from several hundred MHz to several tens of GHz that has to match with an external cavity round trip time. The tolerance towards variations should be in the range of (1-5)% of the pumping frequency[4]. Thus the conventional gain-switching of a diode laser with direct modulation of the pump current at any arbitrary frequency remains one of the simplest and low cost design to obtain high peak power picosecond pulses.

In the past, we have demonstrated a wide, continuous tuning, over a range of 115 nm by using a InGaAs SQW GRIN-SCH Grating Coupled Surface Emitting Lasers (GCSEL) in a simple, flat mirror external cavity under quasi-CW current excitation[5] . This tunability has been recently extended to 132 nm (~14% of central wavelength) in our lab. Our GCSEL chip consisted of two monolithically integrated sections: a 530 μm-long gain section with stripe width of 100μm and a 930 μm-long off-resonance passive grating with a period of 340 nm. The wavelength was tuned by tilting a flat mirror in relation to grating that had been fabricated at the Ioffe Institute, Russia. The grating period was detuned from second order Bragg reflection feedback and hence grating served as the first order outcoupler only. Therefore, our external cavity GCSEL chip did not require any AR coating to suppress the residual F-P cavity mode generation. In this letter, we report the results of a similar GCSEL in an external cavity with a 50% flat outcoupled mirror, but operated in the gain switched regime to obtain high energy, tunable picosecond pulses.

2. EXPERIMENTAL SETUP

The GCSEL chip was driven by unbiased current pulses with FWHM ranging from 1 nsec to 4 nsec. The maximum pulse repetition rate of 10 MHz was limited by the current pulser used in the experiments. The temporal characteristics of the pumping pulses were measured by a CT-1 Tektronix current transformer and a Tektronix 11801B digital oscilloscope. The optical output from the external mirror was coupled into a single mode fiber and sent into a 25-GHz New Focus photodetector. Temporal pulse shapes were measured by the same high-speed scope and the time resolution

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of the whole system was about 24 psec that was determined in a previous experiments with a 10-psec laser diode[6] . The optical pulse energy and peak power characteristics were estimated from the data of average power, repetition rate and temporal shapes of the laser pulses. For simultaneous lasing spectra monitoring, the light from the cleaved facet was coupled into fiber and then measured by an Ando grating spectrum analyzer at a resolution setting of 1 Å.

3. RESULTS AND DISCUSSION.

Fig. 1 shows the optical spectrum (a) and temporal shape (b) of the gain switched pulses from a 10-mm external cavity GCSEL pumped by current pulses with width of 1.6 nsec. In this case the external mirror was tuned close to the gain maximum of 978 nm. The current amplitude was about of 1.9 times above the threshold (600 mA) for given pumping conditions. The spectrum (see Fig.1a) consisted of a main peak which linewidth was within the instrument resolution of 1 Å , and two satellite peaks spaced symmetrical by ~2 Å to the lasing line center. Intensity of these peaks strongly depends on the external mirror alignment and so these may be explained as possible higher order spatial modes.

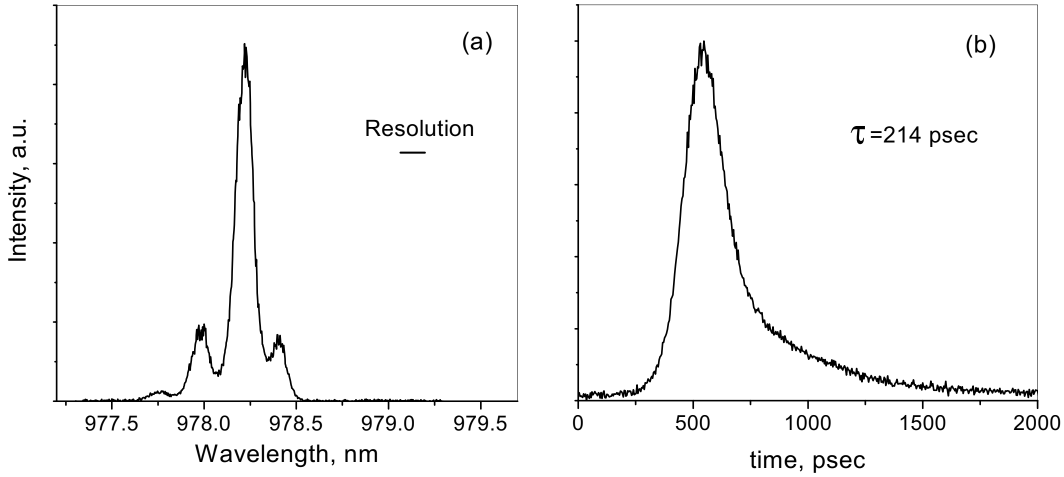

Fig. 1: Spectrum (a) and temporal shape (b) of the gain switched optical pulses from a 10-mm external cavity GCSEL. The pulse energy was 28 pJ

The optical pulse shape (see Fig.1b) had asymmetric temporal profile with longer fall time than rise time that is normal for gain-switched pulse[7] . The laser pulse narrowed with increasing pump current amplitude and the shortest single gain-switched pulse we obtained, had a FWHM of 166 psec with a peak power of ~200 mW. When longer pump pulses (FWHM of 3.4 nsec) were applied, the threshold current went down from 600 mA to 450 mA and the optical pulse shape tended to evolve into multiple relaxation peaks at relatively high current amplitude. As the pump current exceeded I/Ith > 2.5, the width of the first peak became constant at 158 psec limited by fundamental parameters of laser, e.g., nonlinear gain coefficient[7] .

Wavelength tunability of the laser is demonstrated in Fig. 2 which presents the pumping current threshold obtained at different tuning wavelength for a 3.4-nsec pumping pulse. The measured characteristic showed a relatively constant threshold (variation of 20%) for a range of 25 nm, from 960 nm to 985 nm. Such behavior exhibits a better tuning quality compared to the data obtained with the similar tunable external cavity laser in [8] . Total tuning range achieved in our experiment was of ~60 nm (~6% of central wavelength). This range was limited by the current amplitude of our pulsed power supply.

As we already mentioned, shortest gain switched pulses can be obtained by increasing current pulse amplitude to raise the initial inversion of the carrier density. In this case minimum pulsewidth from an external cavity laser is of the order of few cavity round-trip time[7] . To examine a minimum achievable pulsewidth, we also investigated the gain switched pulse generation from another GCSEL device with grating fabricated as a second order distributed Bragg reflector. This on-chip grating resonator provided the shortest effective laser cavity length comparing with the external cavity GCSEL.

Fig.3 shows the data obtained from the second order GCSEL pumped by 3.4 nsec-width current pulses. In this experiment we have obtained narrowest optical pulse with FWHM of 67 psec at current amplitude of I/Ith = 1.6 . Applying the same method we investigated the shortest gain switched pulses from external cavities GCSEL with different distances between external mirror and grating. In this case the external mirror tilt angle kept constant provided lasing wavelength of λ=980 nm. The data obtained in both experiments are plotted in Fig.4 versus the effective laser cavity length that was estimated by summing the external cavity length and the effective length of the GCSEL waveguide. These results demonstrate that the gain switched pulsewidth increases with cavity length and narrowest tunable pulses can be achieved if a shorter external cavity GCSEL is constructed using MEM technology.

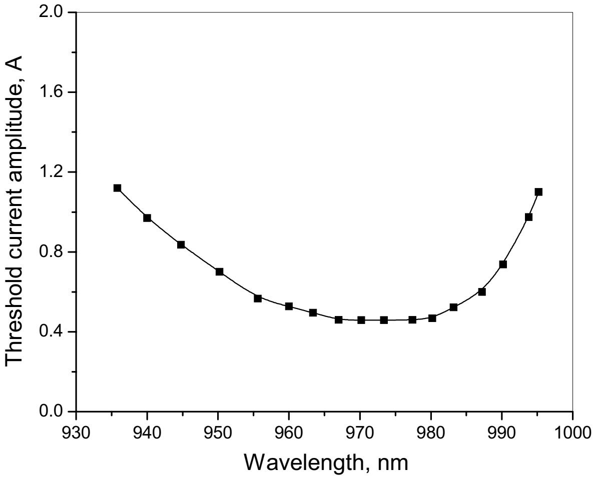

Fig. 2: Current threshold vs. tuning wavelength for a 10-mm external cavity GCSEL. Pumping pulse width was of 3.4 nsec.

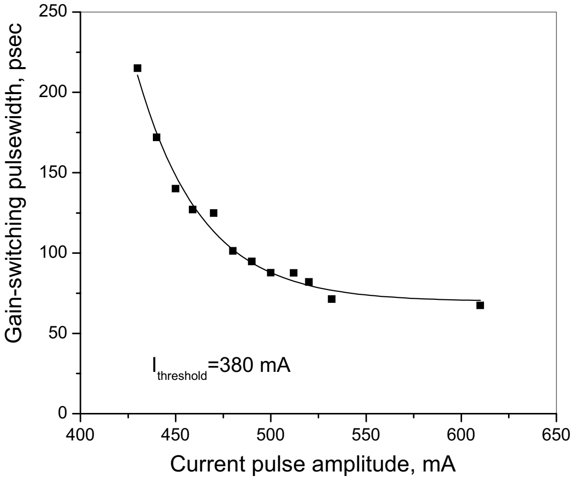

Fig. 3: Gain-switched pulsewidth vs. current pulse amplitude for a second order Bragg GCSEL.

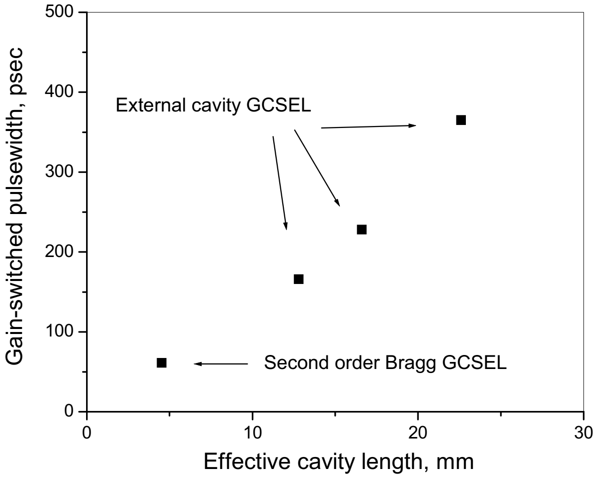

Fig. 4: Minimum gain-switched pulsewidth vs. effective laser cavity length

4. CONCLUSION

The gain switched GCSEL has multiple advantages as discussed in [5] : non-requirement of AR coating and large surface area of emission giving higher output power limit and lower beam divergence than conventional FP devices. A simple flat mirror close to the output grating forms a small external cavity that allows one to obtain tunable gain-switching pulses with picosecond duration. We believe that such compact and optically simple external cavity GCSEL will find a multiple applications in optoelectronics and in time-resolved spectroscopy as well.

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