STSM REPORT

STSM Application number:

COST-STSM-BM1205-27569

STSM Grantee:

Dr. IAKOVLEV VLADIMIR

STSM title:

Investigations of wafer-fused VCSELs in 1300-1500 nm wavelength range using self-interferometry

Home Institution:

EPFL

Host Institution:

UNIVERSITA DEGLI STUDI DI BARI

STSM period:

2015-05-21 00:00:00 to 2015-05-30 00:00:00

STSM purpose:
To investigate a new generation of wafer fused VCSELs in the self-interferometry set-up available at host institution, first of all it is expected to evaluate the emission line-width under external feed-back, a parameter that will set the limits of applicability of such a lasers for skin cancer detection.

Description of the work carried out during the STSM:

The set-up was calibrated using a Fabry-Perot laser and then it was started a series of measurements using samples of wafer fused VCSELs. Measurement of linewidth were obtained and scattering experiments on tissues were planned.

Description of the main results obtained:

(1) The set-up was adjusted to specific package of the samples.

(2) It was established the set-up parameter window allowing clear observation of the impact of feedback on VCSEL operation using external photodiode, built-in photodiode as well as VCSEL voltage.

(3) It was measured the value of 20 MHz for emission linewidth of the VCSEL emitting in 1300 nm wavelength range at 5.5 mA operation current.

Mutual benefits for the Home and Host institutions:

The work is of mutual benefit for both home and host institution with the goal of identification of usability of such VCSEL devices for perfusion measurement using self-interferometry due to deeper penetration of 1400 nm wavelength in biological tissues with respect to the 850 nm.

Future collaboration with the Host institution.

Both host and home institution agree to continue investigation of 3 set of devices at 3 different emission wavelength and in a wider current and temperature range. Experiments were planned to be conducted in Bari on a set of devices kindly provided by EPFL.

I confirm that the information above is correct and that this STSM has set the basis of a profitable collaboration between the two groups involved.

LASER LINEWIDTH MEASUREMENTS OF A NIR VCSEL

Self-mixing in semiconductor lasers occurs when a portion of the light emitted is back reflected by an external target into the laser cavity. The laser mode oscillating in cavity laser field interacts coherently with the laser beam back-reflected and originates variation in the laser parameters as the emitted laser power, junction voltage, laser threshold and lasing frequency. These detection scheme has several advantages including sensitivity to the phase and power of the interferometric signal, a high signal to noise ratio due to the coherent scheme detection and , by revealing the voltage variation across laser terminal, the laser can be both source and detector.

In a self-mixing interferometer the saw-tooth like fringe period corresponds to a target displacement of $\lambda_{QCL}/2$ and any fast switching is generated each time the interferometric phase in the external cavity was varied by 2π. Due to the frequency fluctuation of the laser output, the phase of the interferometric electrical field changes with time randomly and the measurement of the phase noise allows to estimate the laser linewidth. Because of the phase noise the switching time corresponding to consecutive acquisition by the oscilloscope of the same fringe changes, revealing a fluctuation Δt as shown in Figure1(a). Therefore the phase noise can be estimated by acquiring with the oscilloscope a histogram of the period of a specific interferometric fringe. The statistical distribution of the fringe period can be analysed by a Gaussian fit (Figure 1(b)). The mean value and the standard deviation, corresponding to the fringe period and the root mean square of the switching time respectively, allow to estimate the root mean square (RMS) of the phase noise. The laser linewidth is estimated by the slope of the linear fit of the RMS phase noise as a function of the target distance from the laser according to the method descripted in the reference[1]. Figure2 shows the experimental layout, where the external cavity is closed by a remote target on a piezoelectric actuator. The laser was a VCSEL emitting at 1310nm and the interferometric signal was revealed using an external photodiode. The modulation of the emitted laser power is shown in Figure3.

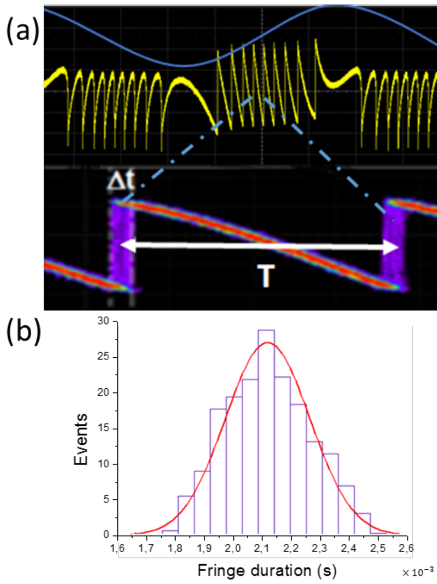

Figure 1: (a) A representative self-mixing waveform saw-tooth at moderate strength of the optical feedback. Below the enlargement of the central fringe corresponding to the linear range of the sinusoidal displacement of the target. The blu trace is the sinusoidal displacement of the target. (b)The period of the fixed fringe is acquired at least 500 times to obtain the histogram of the period analysed by a Gaussian fit.

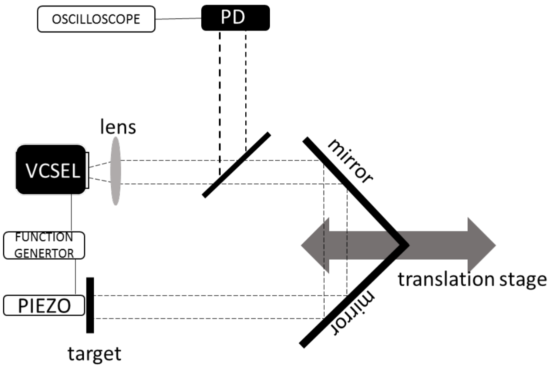

Figure 2: experimental set-up representing the self-mixing interferometer to measure the laser linewidth.

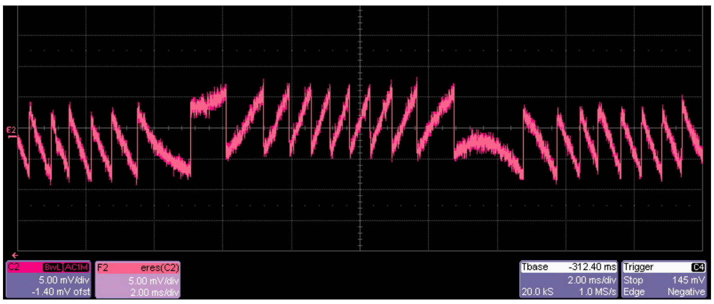

Figure 3: self-mixing signal by external photodiode.

First of all the set-up was calibrated by measuring the linewidth of a Fabry-Perot diode laser emitting at 1500nm. Then the source has been replaced by a VCSEL emitting at 1310nm. Figure 4 shows the L-I curve of the VCSEL in the range from the current threshold to 12mA. The characteristic curve was acquired also by polarizing the laser beam along two orthogonal direction.

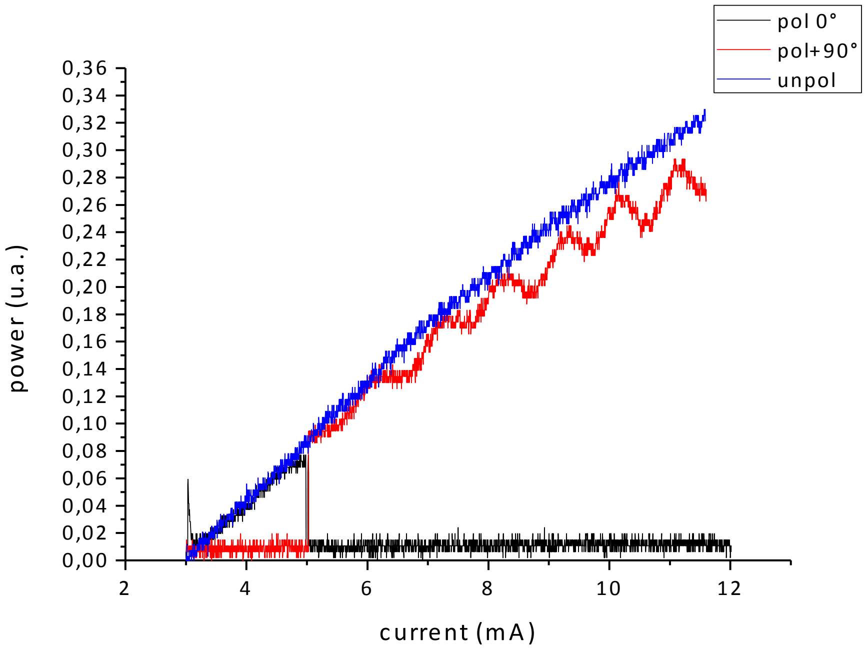

Figure 4: L-I curve of the VCSEL emitting at 1310nm. The blu curve is the power emitted from the unpolarised lase. The black one and the red one represent the power from the polarized beam along the two orthogonal direction.

The phase noise was calculated by acquiring the fringe period corresponding to different length of the external cavity when the target position is varied from 0,5m to 1,1m.

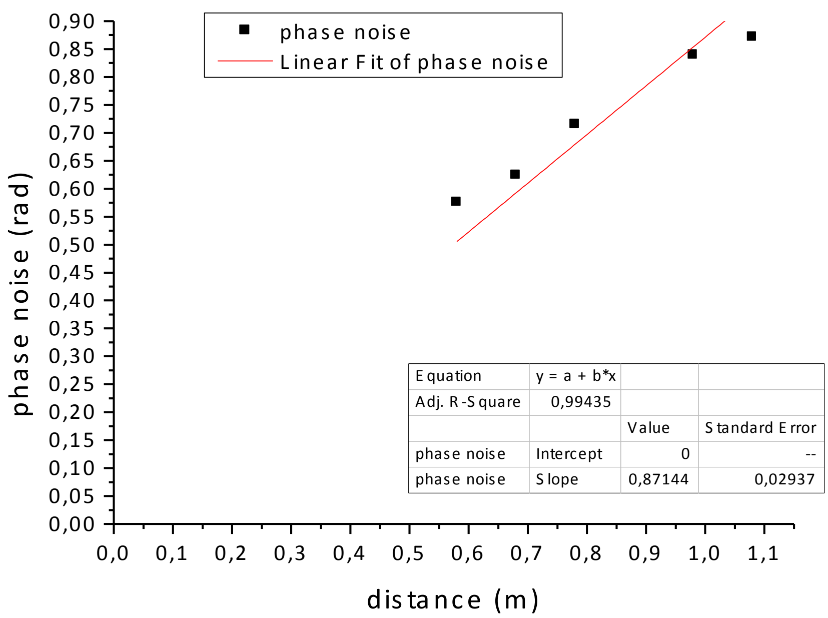

Figure 5: RMS phase noise dependence on the target distance: the laser linewidth was estimated from the slope of the fitted curve. The drive current was 5.5mA.

A linewidth of about 20MHz was estimated.

Future plan consists of measuring the VCSEL voltage signal to get rid of the external photodiode and to compare linewidth at different feedback levels and injection current.

References

1 Giuliani, M. Norgia, “Laser diode linewidth measurement by means of self-mixing interferometry,” IEEE Phot. Tech. Letters, Vol. 12, No. 8, pp. 1028-1030, 2000.