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# Experimental comparison of extended-cavity passively mode-locked 1.5 μm quantum well lasers with anti-colliding design and self-colliding design

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In this paper we present an experimental verification of a prediction of significantly improved performance of an integrated passive mode-locked laser (PMLL) through the use of an anti-colliding (AC) design comparing with a self-colliding (SC) scheme. The most commonly used design is the linear SC cavity. In this scheme a saturable absorber (SA) is placed close to the high reflectivity facet, which allows the pulse to interact with itself within the SA. However in [1] it was shown theoretically that an AC design where the SA is placed next to the low reflectivity output coupler is advantageous. It leads to a higher stability, an increase of optical output power and shorter pulses due to the weaker saturation of the gain and enhanced modulation of the SA in comparison with symmetrical mode-locking (SML) and SC scheme. A marked improvement in the performance of two-section cleaved facet PMLLs was achieved by the introduction of a low-reflectance coating at the SA facet and a high-reflectance coating on the other facet in comparison with a non-coated device (SML configuration) in [2]. However, the deposition of the coatings may lead to changes in the reflection spectrum.

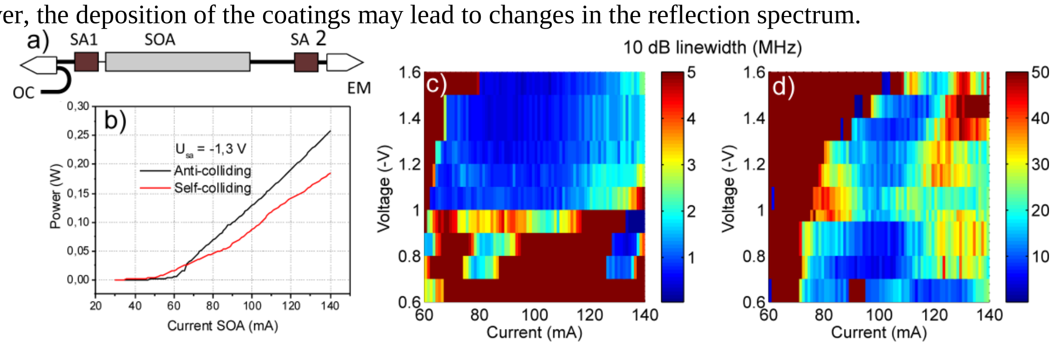


**Fig. 1** a) Sketch of the linear 7.4 GHz PML. b) Optical power as a function of current injected in semiconductor optical amplifier (SOA) for both configurations. A map of the RF linewidth measured at 10 dB level for the SC (c) and AC (d) configurations. Please notice the difference in colour scale of a factor 10 between (c) and (d).

To check and verify the improvement of performance of the laser in an AC configuration compared to one in a SC configuration, a linear PMSL of 7.4 GHz was designed using broadband on-chip passive reflectors as a mirrors. Both schemes can be realized in the same device by switching electrical connections only. The laser cavity of 5.4 mm (Fig. 1 a)) was composed of two 100 μm active sections (SA1 and SA2) and one 2000 μm SOA section which were based on a multi-quantum well core, passive waveguides and multimode interference mirrors of 50% and 100% reflectivity. The position of SA can be varied from the output coupler (OC) side to the the end mirror (EM) side by applying reverse bias on SA1 or SA2 respectively.

To study the dynamics, the optical power, RF spectra from a 50 GHz photodiode and autocorrelation (AC) traces were recorded for a wide range of operating conditions for both configurations. Fig. 1 (b) shows the dependencies of the fiber-coupled optical power for both configurations as a function of the current injected in the SOA for $U_{sa}$ = -1.3 V. As predicted, placing the SA near the OC (black curve) leads to higher optical output power compared to the case when the SA is near the EM (red curve). With increasing reverse bias voltage on the SA, the power difference between the two configurations also increases up to 3 dB. In order to compare the stability of the pulse train of both configurations, the linewidth of the RF peak for various operating conditions was measured. Fig. 1 (b,c) show maps of the RF linewidth measured at the -10 dB level for various operating conditions for the SC and AC schemes respectively. Please notice that the colour scale for the linewidth in Fig. 1 (c) is ten times larger than the scale used in Fig. 1 (b). These results clearly demonstrate that placing the SA next to the low reflectance mirror leads to a reduction in timing jitter in comparison to the case where the SA is placed next to the EM. Analysis of autocorrelation traces for the wide range of bias conditions show an improvement in pulse duration as well in AC configuration. In this case the minimum achieved autocorrelation width was 7.5 ps, whereas minimal width in SC configuration was 22 ps.

We can therefore confirm that there are clear advantages of using an AC design for a PMLL. This work has been funded by the Paradigm project (FP7/2007-2013 under grant agreement 257210 PARADIGM).

## References

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