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Mode locked laser systems on InP integration technology platforms

Erwin Bente[1], Sylwester Latkowski[1], Valentina Moskalenko[1], Mònica Llorens-Revull[1], Kevin Williams[1]
[1]COBRA Research Institute, Department of Electrical Engineering, Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, The Netherlands
* e.a.j.m.bente@tue.nl

In recent years a number of Indium phosphide (InP) based photonic integration platforms have emerged which enable complex optical circuits containing optical amplifiers, (electro-optic) phase modulators, low-loss passive waveguides, on-chip mirrors, splitters, filters etcetera [1]. These capabilities provide a freedom in the design of planar integrated mode locked laser sources which is starting to resemble the freedom one has when using bulk optics, but with the added advantages of stability and compactness. This development thus raises the expectation that integrated mode locked laser (MLL) systems can be realised with a performance that supersedes planar waveguide devices that only use an active layer stack and bring integrated MLL devices to applications. Applications of short optical pulses and wide coherent optical frequency combs that can be generated by mode locked lasers e.g. in microwave photonics, communication or biophotonics can present widely varying requirements for the laser system. In a particular technology platform the composition of the layer stack is a given but a large degree of freedom in the design of the laser circuit is available to meet the application requirements. In this paper results are presented that have been obtained at our institute utilising standardised integration platforms on InP that illustrate the advantages and possibilities.

Many planar semiconductor Fabry-Perot lasers show evidence of phase coherence between the modes to some degree. However the basis for every high quality system that is based on quantum well gain material is a passively mode locked laser using a saturable absorber (SA). Such an SA is typically realised using a reverse biased SOA section. The ability to have active and passive waveguide elements in the integrated laser cavity has a number of advantages for such devices. These are illustrated in a design of a mode locked ring laser with a repetition rate of 20GHz as presented in Figure 1 [2].

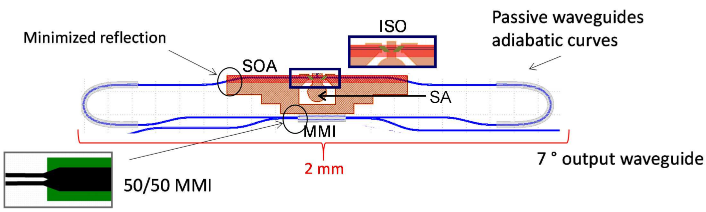

Fig. 2. Example of a mask lay-out of an integrated mode locked ring laser with 20GHz repetition rate. Specific measures to minimize on-chip reflections are pointed out [2].

This device has shown a record frequency comb width and a sub-picosecond output pulse duration was demonstrated. The length of the semiconductor optical amplifier (SOA) and the saturable absorber can be much shorter than the laser cavity and thus are to a large extent decoupled from the repetition rate. This helps with suppressing relaxation oscillations. The relative position of the SOA and SA sections can be varied to control e.g. the relative power in the two directions in the ring. There is much more control over the output coupler which can now be a passive device, in this example a 2 by 2 multi-mode interference coupler (MMI). Such a device has a clearly defined output coupling fraction since it is a passive device. For reliable operation of the MLL it is important that reflections from the intra-cavity components (foundry defined building blocks) are minimised e.g. using methods as pointed out in Figure 1. Using linear cavity designs to establish the optimal position of the SA [3], and the use of distributed Bragg reflectors for tuning the MLL were investigated. We will present the most recent results obtained with such mode locked lasers.

By applying an RF signal the stability of the repetition rate of the MLLs, i.e. the frequency spacing between the lines in the spectral comb, can be improved significantly. If one manages to stabilise the frequency offset of the frequency comb as well, one has stabilised the whole comb. Ongoing research on stabilising the frequency comb of 2.5 GHz repetition rate ring MLL systems [4] using a CW single frequency laser as a reference as well as the possibility to develop a single chip for an integrated Fourier transform spectroscopy system based on two stabilised MLLs will be discussed.

The photonics integration technology allows one to manipulate the output from mode locked lasers using a special amplifiers design or a more complex pulse shaping circuit [5] on the same chip. Since such manipulation is often required in applications, e.g. to achieve the shortest pulse inside an optically dispersive sample. In such applications it is the fixed phase relation between the laser modes that is the most important property of the laser output. Operating such circuits becomes increasingly complex since it involves many electrical signals and the integration of the control electronics with the laser system chip as well as the control strategies for such systems are important research subjects for the future.

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