Regenerative Stabilization of an Active Mode-Locked Laser

Introduction

Active mode-locked lasers (MLL) are an attractive source for pico-second pulses. An active mode-locked laser consists of a laser cavity with an amplitude modulator. When the modulator is driven with a signal whose frequency is an integral multiple of the frequency corresponding to the cavity round trip time, the cavity modes are phase-locked with respect to each other resulting in a pulse train. Such pulses are suitable for applications such as carrier recovery in optical communication and photonic analog to digital conversion. However, the pulses are influenced by a variety of instabilities such as pulse breaking due to non-linearity in the optical fiber, and cavity length changes due to environmental fluctuations. Electronic compensation techniques are typically used to counter these instabilities and make the pulse train stable.

Regenerative stabilization

Regenerative stabilization is an effective method for the stabilizing the active mode-locked lasers. One of the problems faced in the regenerative scheme is the coupling of the amplitude noise back to the cavity through regenerative feedback. This problem has been previously addressed using a phase locked loop (PLL) based regenerative scheme. In our work, the regenerative feed back system is designed based on saturation of electronic amplifier to decouple the amplitude fluctuations in the regeneration system.

The block diagram of the regeneratively mode-locked laser system is as shown in Fig. 1. Regeneratively mode-locked MLL consists of two parts namely the optics and the control electronics. The optical portion is a polarization maintaining mode-locked loop consisting of a gain medium, isolator, output coupler and an amplitude modulator biased in the linear region of its transfer curve. The feedback electronics consist of an amplifier stage, a band-pass filter and a phase–shifter.

In this scheme, the required pulse repetition rate (integral multiple of frequency corresponding to the cavity round trip time) is extracted from the photo-detected pulse train using the band-pass filter. The recovered RF carrier is phase shifted to compensate for the electronic delay and then fed back to the modulator in the mode-locked loop. Resonant noise oscillations in the cavity, at the pulse repetition frequency, will initially seed the optical pulse formation process. The pulse train gets further defined through the regenerative process.

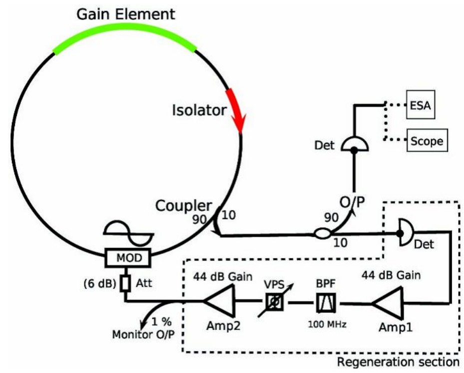

Figure 1. Block diagram of experimental setup.

We built a cavity with a fundamental frequency of 26 MHz, and chose a band-pass filter centred at 101 MHz, with a bandwidth of 11 MHz. This allowed the fourth harmonic at 104 MHz to be amplified and fed back into the cavity. The experimentally obtained 4^{th}harmonic pulse train is shown in Figure 2.

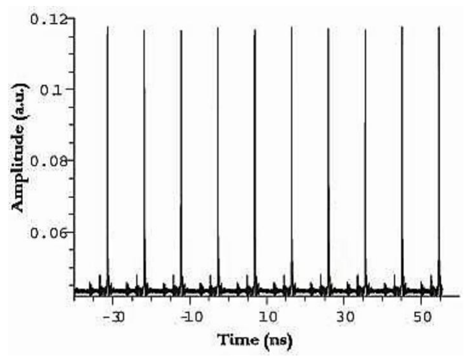

Figure 2. Pulse train with pulse width of 68 ps.

Conclusion

The energy jitter and the timing jitter were evaluated from the fundamental and the tenth harmonic frequency component and found to be 0.7% and 0.036% respectively. Present work is focused on extending this regenerative scheme to be independent of the repetition rate.

Publication

A. Bekal, K. Vijayan, B. Srinivasan, "Study of Pulse Stability Enhancement in Regeneratively Mode-Locked Fiber Laser," to be presented in Photonics 2012 Conference.

Photonics Group
Department of Electrical Engineering, IIT Madras
http://optics.iitm.ac.in

A. Bekal, K. Vijayan
B. Srinivasan