EECE 327

Analog and Digital Electronic Circuit Design

List of the Suggested and Sponsored Projects

Spring 2004

A- Mobile Robot Projects

1 – Automatic Charge Control Circuit

2 – Mobile Robots with Bio Sensors or Chemical Sensors for Detection and Mapping

3 – Bar-Code Reading for Localization and Guidance

4 – Optical Data Communication

5 – Muscle Wires as Manipulators

6- On-board Camera

7- Electronic Compass for Localization

8 – Line Following Circuits

9- Dual Chip Lobot Jr. Using Xilinx FPGA Chip

10 -LabView Interface for Navigation

B- Laser Research Modules

1 – Phase Shifter Circuit

2 – Slow Feedback loop- locking Amplifier

3 – Phase-locked loop Combined with Servo Control.

4 – Average Frequency Control

5 -Traveling wave Gate operated by Regenerative Feedback

6 – Analog Rectangular to Polar Converter

C – System and Control Lab. Modules

1 – Signal Processing Experiments Using LabView

2 – Image Recognition Based on IMAQ

3 – Magnetic Levitation Experiment Set-up

4 – Position Control Experiment Set-up

5 – Speed Control Experiments Set-up

6 – Inverted Pendulum Analog Control

C- Miscellaneous

1 – Electronic Flute

1 Phase Shifter

Purpose The purpose of this phase locked loop is to create a fixed amplitude oscillation of continuously adjustable phase, at a frequency set by a 10.6 MHz oscillator. The phase should be adjusted over a range of 2 π. The input signal is about 100 mV.The output is the input (RO) to a frequency mixer (ZAY-3 minicircuits) with 23 dBm LO and 15 dBm RO. The output should be 15dBm on 50 Ohms, with no more than 1% amplitude change over the full range of phase change. (Another circuit is required for 16.1 MHz).

Proposed approach Phase shifters are commercially available, but the phase adjustment results in a signal distortion and a change in amplitude. By combining the phase shifter with a phase locked loop, it should be possible to maintain a constant amplitude of the output, for any value of the phase adjustment.

Mixer combinations (10.6 MHz is out of the range of the VCO's.One approach is to combine (frequency mixer) the output of two VCO's (ex POS-25 with 20 MHz and POS-50 with 30.6 MHz)in order to achieve 10.6 MHz.)

2 Slow Feedback loop- Locking amplifier

Objectives There are two successive objectives:

1. To detect the weak fluorescence signal (or another measurement) from rubidium vapor excited near a two-photon resonance by a mode-locked laser, of which the frequency and repetition rate are scanning.

2. use this signal as an error input in a feedback loop to correct the pulse frequency/repetition rate.

Parameters The fluorescence signal is measured by a photomultiplier, terminated at 10 kΩ. The signal is in the range of 10 to 200 mV, over a dc and low frequency noise (at least 200 mV), and a modulation at 800 kHz.

A frequency modulation is applied to the exciting beam, (at a frequency sufficiently different from 800 kHz).The fluorescence had been detected with a photomultiplier. The circuit needed here is essentially mixing output of the photomultiplier with the modulation frequency, with 2π phase adjustment to adjust the product of the two to max or min desirable. In other words a phase sensitive detection of the fluorescence should provide an output to feedback either in a high voltage amplifier or in a acousto-optic modulator drive to keep the frequency of the laser on resonance. The integration time should be between 30 seconds and 5 minutes(adjustable).

3 Phase-locked loop combined with servo loop – repetition rate control

3.1 Statement of the problem

A very weak signal ¡1 mV is recorded by two photo-detectors PD1 and PD2 (first order off the grating from reflected signal of reference cavity). The difference signal between the two photodetectors has to provide the error signal for the repetition rate.There is slightly stronger signal (10 mV) from another photodetector PD0 (zero order off the grating from reflected signal of reference cavity) which is used to control and stabilize the average frequency of the mode locked laser.
The signal from each detector is very weak and contains the following frequencies:

1. 100 MHz, because the signal emanates from a mode-locked laser operating at that frequency;
2. 10.6 MHz, because that beam is modulated at that frequency, providing two sidebands from the 10.6 MHz
3. The relative amplitudes of the sidebands changes, because the signal is reflected from a Fabry-Perot with reflection peaks narrow compared to 10.6 MHz.

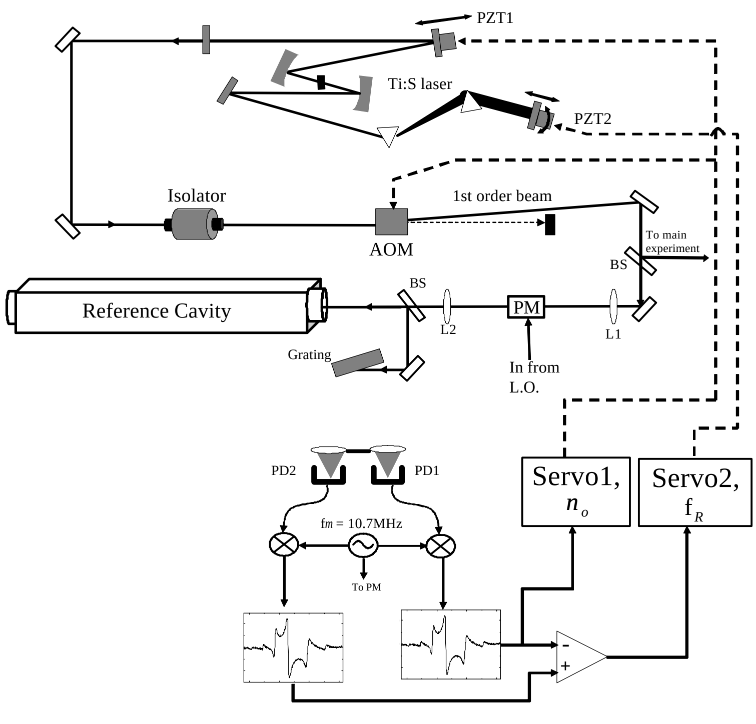

Figure 1: Sketch of a Mode locked laser and the stabilization loop.

The signal from each photodetector has to be mixed with the reference 10.6 MHz, to provide the error signal required to drive a piezo or a combination of piezo to stabilize the laser. Since the signal is weak, each photodetector could be used to drive a phase locked loop, of which the output would be sent to the corresponding mixer.

3.2 Average frequency control (locking to a mode of reference cavity)

The 10.6 MHz signal of PD0 can be used to control the average frequency of the laser. There should be a manual adjustable knob to adjust this signal to the maximum and with a switch the loop will be closed and the circuit will send the proper signal to piezo and Acousto-optic modulator to keep this signal at maximum. The control of this loop is independent of the next loop (repetition rate). The repetition control loop can be open while average frequency loop is closed and locked.(adjustable gain ratio for piezo and acousto-optic is desired, to improve the locking)

3.3 Repetition rate control (locking to different mode spacings)

The difference signals from PD1 and PD2 at 10.6 MHz is used as an error signal. There should be a manual control to scan the piezos. The unity gain frequency of the servo loop should be 1 kHz (resonance frequency of the piezo). The piezo-element that is being driven has several possible "lock" resonances in its translation range. It is desirable to set close the feedback loop on the first of these resonances, than apply a pulse that displaces the setting point of the piezo to the next mode of the cavity. This pulse should be shaped to avoid the ringing of the piezo, which would throw the feedback loop out of lock. We will perform some measurements on the frequency response of the combination piezo-mirror.

4 Servo-loop for Synchronously pumped optical parametric oscillator

There are two alternatives for this stabilization. The first one is derived from the now classical "Pound-Drever-Hall" stabilization. The second one is a direct feedback loop, no involving any phase modulation nor dither frequency.

4.1 Pound-Drever-Hall approach

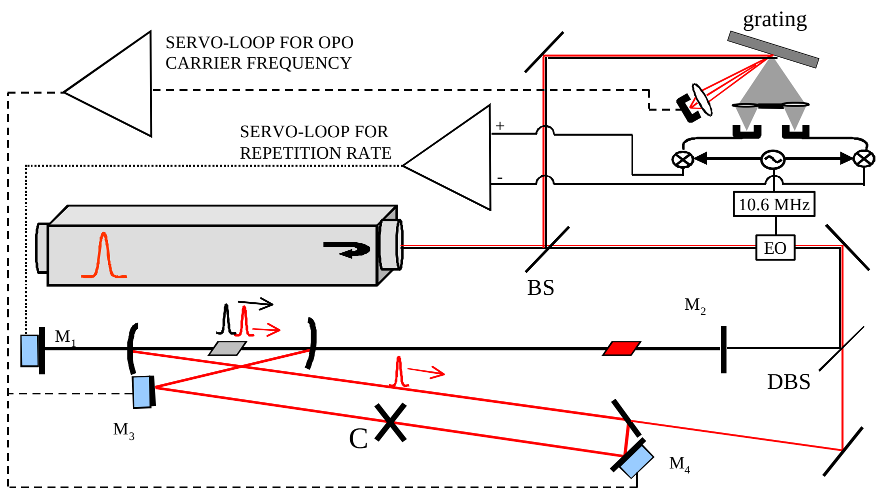

Figure 2: Sketch of a possible ring OPO geometry, and the stabilization loop.

The beams of the pump laser and the OPO signal are combined by a dichroic beam splitter DBS. Both beams are given the same phase modulation at 10.6 MHz by an electro-optic crystal. The reflection of the reference cavity (1/2 the cavity length of the pump) is dispersed by a grating. The difference between the two errors signals taken at the edges of the pump spectrum are used to control the cavity length (mirror M_1) of the pump laser, hence the repetition rate of the system. The wavelength of the OPO signal is unaffected, since it is solely determined by the OPO cavity perimeter. An error signal is thus derived from the dispersion of the grating at the signal wavelength, and mixed with the modulation. The correction signal is send simultaneously to the piezo drivers of mirrors M_3 and M_4, located symmetrically with respect of the pulse crossing point C. It is indeed essential to apply symmetrically the correction to the signal cavity simultaneously to the two circulating pulses, in order to prevent a broadening of the beat note bandwidth by the motion of the cavity length correcting mirrors.

Essential characteristics:

- Modulation frequency: should we go lower than 10.6 MHz? As opposed to other laser systems, we are facing a very large amplitude noise.
- Detectors from the dispersed Tisapphire laser: a few mV amplitude — preamp required — modulation at 10.6 MHz, pulse repetition rate at 80 MHz (to be filtered out).
- detector from the OPO signal – possibly as low as 100 μV; modulation at 10.6 MHz, pulse repetition rate at 80 MHz, large low frequency (typically mechanical resonances) noise.

- The control signal for the repetition rate may have to be split in a fast ($> 5kHz$) and slow component. The fast component is to be applied to an acousto-optic modulator controlling the pump power. The slow component is applied to the piezo. Both drivers for the piezo and the acousto-optic modulator take an input of 0 to 1 V.
- Most disturbing for the measurement of the beat note of the ring laser are the slow, large amplitude motions. Therefore, the control loop should be designed for a piezo with its resonance between 3 and 5 kHz. Faster stabilization should not be considered at this stage.

4.2 Feedback loop

In the case of the optical parametric oscillator OPO, the repetition rate of the OPO is solely determined by the cavity length of the pump laser. A simple method is to use a frequency synthesizer at the correct frequency, and to synchronize the laser repetition rate to that oscillator reference. The technique could be simply to use the oscillator as an external reference for a phase locked amplifier (or L.O. input to a mixer), the pulse train into the signal input (or RF input of a mixer), and send the output to a piezo controlling the cavity length — hence the repetition rate.

The average carrier frequency of the OPO is extremely sensitive to its cavity length. With the repetition rate set by the pump laser, a change in cavity length has to be compensated by a change in group velocity of the signal pump resonating in the OPO cavity. This group velocity is wavelength dependent. A simple method is to disperse the spectrum of the output beam from the OPO, and use two detectors selecting the leading and trailing edge of the spectrum. The difference between the two signals is amplified, and used directly to control a piezo that adjusts the OPO cavity length.

5 Travelling wave gate operated by regenerative feedback

A long fiber ring laser operates at 1 MHz. A detector senses a signal at that frequency corresponding to one output of the laser. This output has to be amplified, and made to generate two sequences of two pulses of duration ≤ 1 ns, which should drive two modulators or gates.

The time delay between the sequence $1 \rightarrow 2$ should be equal to the optical delay time τ for the light passing through the fiber from one modulator to the next one. That pulse sequence should be followed after a time adjustable from 1 ns to 500 ns by a reverse sequence $2 \rightarrow 1$, with the same interpulse spacing of τ.

The synchronization is provided by an optical detector which samples the optical signal passing through the fiber. Before a pulse train is established, this optical signal is only a very weak modulation at 1 MHz. The challenge is to have a circuit that can start the oscillation and sustain it.

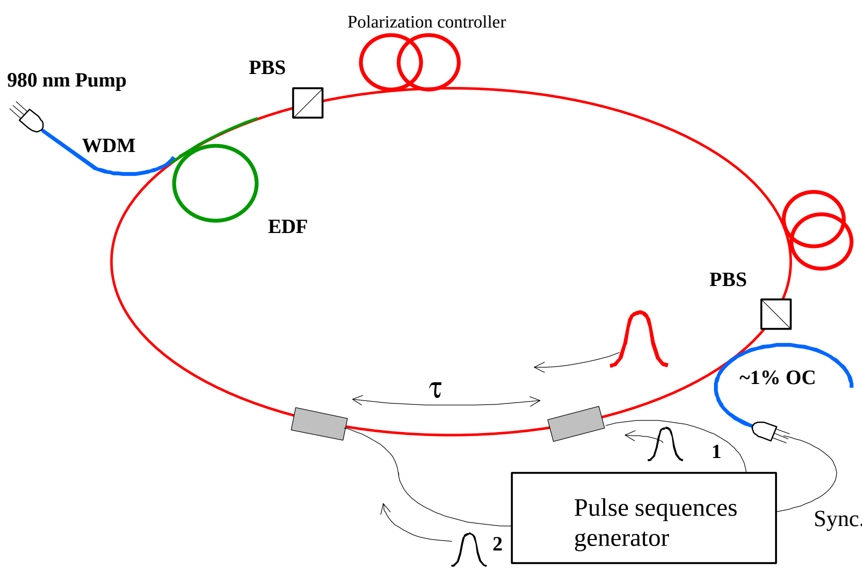

Figure 3: Sketch of the fiber ring laser, and bi-directional synchronization.

6 Electronic sound control for a flute

Electronic flute do exist. What does not exist are real flute with controllable amplifier chain for each note or key. The player would like to have control of filters and amplifiers associated with each key. A single micro can still be used – for instance a miniature microphone inserted in the body. There is a little lever associated to each key. Rather than making a contact, it should be a capacitance switch (proximity switch). One possibility is to have a 1 MHz oscillator, capacitively shorted each time a key is activated, and the suppression of the oscillation would gate the appropriate acoustic amplifier. The electronic challenge is here to "channel" the signal from a microphone into as many amplifier systems as there are key. Depressing a key should "open" the corresponding amplifier channel. The "switching" should occur in a time short compared with the period of any acoustic wave.