# High Q, low phase noise RF generation of optoelectronic oscillators using different topologies

O. Eltantawy[1], I. Sayed[2], H.Elgamal[3], M. Shalaby[4], A. Elhennawy[5]

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**Abstract: We present experimental results of Opto-Electronic Oscillators (OEOs) [1] with different topologies (Basic scheme OEO, Optical resonator OEO, and Double loop OEO) [2] to generate RF signal with high stability, low phase noise, and high quality factor for the use in special applications like in radar measurements. This is achieved by the employment of an optical fiber as a delay line to profit from its advantages as its low loss, lower cost, less volume, high immunity to electromagnetic interference, and less weight compared to an electrical transmission line. An optoelectronic oscillator makes use of a CW laser source as the source of energy instead of the DC supply in its electronic counterpart. An optical modulator plays the role of a transistor in converting DC energy to RF energy. The feedback circuit contains a filter to select the oscillation frequency plus an amplifier and a phase shifter. The amplifier gain is adjusted such that the loop gain at steady state is equal to unity. The phase shifter is adjusted such that the total phase shift at the oscillation frequency is multiples of 2$\pi$.**

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## 1. Introduction

Microwave oscillators capable of generating spectrally pure signals at gigahertz frequencies are important for communications, navigation, radar, precise tests and measurements, and other applications. Performance of these oscillators is limited by the achievable quality factor Q of their resonance elements and by their sensitivity to environmental perturbations. High purity signals can also be obtained using techniques of photonics, which is free of some of the intrinsic limitations of ultra-high frequency electronics mentioned above. In particular, the opto-electronic oscillator (OEO) is a photonic device that can produce spectrally pure signals at many tens of GHz . A generic scheme of the OEO is shown in Figure 1. Light from a laser is amplitude-modulated by an electro-optical modulator (EOM) and then is sent into a fiber delay line followed by a photodiode. The microwave signal of frequency $w$ from the photo detector output is amplified and fed back into the EOM. This system oscillates if the amplification in the closed loop exceeds the loss. The microwave amplifier may be unnecessary if the EOM efficiency and the photodiode RF output are sufficiently high.

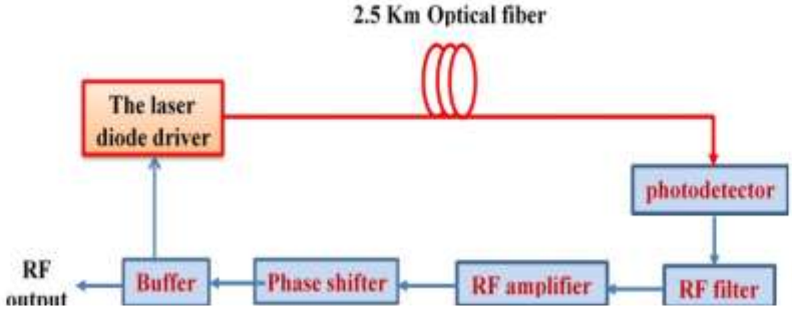


Fig. 1

## 2. Setup

The Opto-Electronic Oscillator Consists of two main parts:

- Electrical part.
- Optical part.

### 2.1. The Electrical Part

The electrical part contains four main components:

- Band-pass Filter.
- Amplifier.
- Phase shifter.
- Buffer.

### 2.1.1. The Band pass filter

We used the RF LC tunable filter (Fig. 2.1).

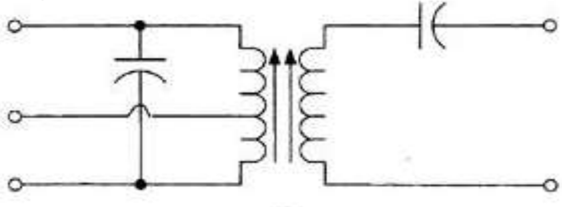


**Fig. 2.1**

This type of filters offers a high quality factor and it can be tuned and adjusted easily in the range 350- 500 kHz

### 2.1.2. The Amplifier

Non- inverting Amplifier is used by using Op-Amp LF 351N.

### 2.1.3. The Phase Shifter

A phase shifter using op-Amp LF 351N is used as shown in Fig. 2.2.Where$\emptyset = tan^{-1}(WRC)$

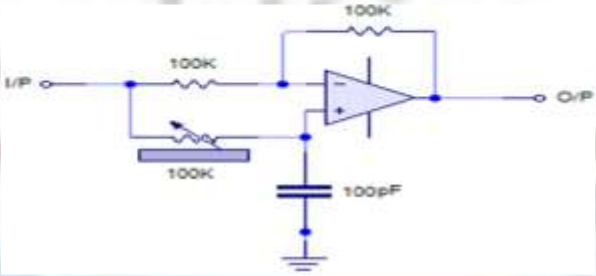


**Fig. 2.2**

### 2.1.4. The Buffer

A buffer using op-Amp LF 351N is used to prevent loading effects from the laser diode driver circuit and the phase shifter.

### 2.2. The optical part

As a result of the different topologies the optical part contains four main components:

- The Laser Diode Driver.
- Delay line
- Optical coupler, and
- Photo Detector.

### 2.2.1. The Laser Diode Driver

The Laser Diode driver acts as an intensity modulator at λ=1310nm.The Laser diode driver converts the input electrical signal to optical output signal.

The laser diode output on the OSA is shown in Fig. 2.3

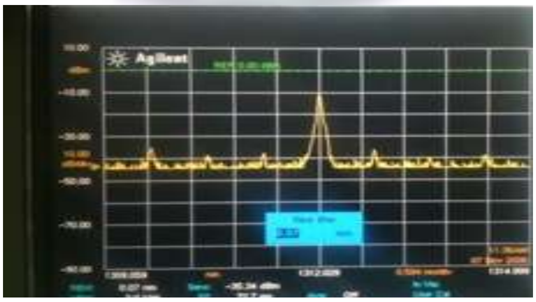


**Fig. 2.3**

### 2.2.2. The Delay Line

The delay line used is an optical fiber with the following parameters:

- Single mode silica fiber.
- 2500m ,2.5m long.
- α=0.35 dB/Km at λ=1310nm
- Disp.: -1.9ps/km*nm

#### 2.2.3. Optical coupler

Two types are used 50 50 and 90 10 optical coupler.

2.2.4. The Photo Detector

The Photo detector used is an InGaAs Amplified detector works at λ=700-1800nm.the scale factor of the detector is 0.01Volt/µW.

## 3. Results

When first setting up the system we use the open loop configuration to adjust the input signal (from the signal generator) with the output signal to bein phase and having same amplitude. After adjusting the open loop configuration and getting sure the input and the output are the same in amplitude and phase we close the loop to operate in the closed loop configuration and measure the output.

### 3.1. Open Loop Configuration

The open loop configuration as shown in Fig. 3.1 is used when first setting up the device to adjust the input (from the signal generator) with the output signal to be in phase and having same amplitude.

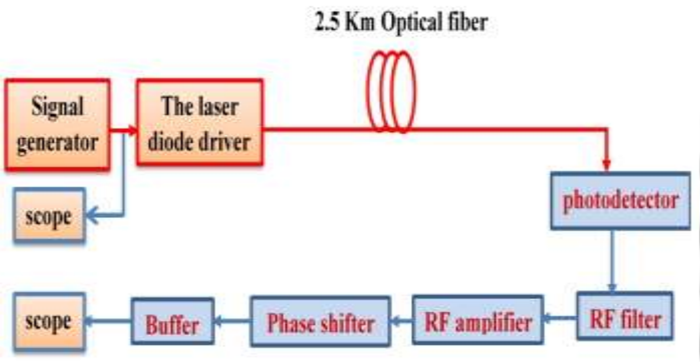


**Fig. 3.1**

The aim of the open loop configuration is to adjust the input and the output as shown in Fig. 3.2

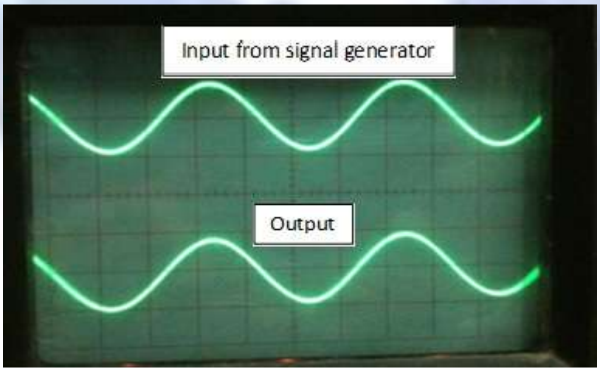


**Fig. 3.2**

### 3.2. Closed Loop Configuration

After configuring the open loop configuration and adjusting the input signal with the output, we close the loop and measure the output . As a result of the different topologyies, the output will be different, as we'll show

3.2.1. Basic scheme OEO

A basic scheme of the OEO is shown in Fig. 3.3 Light from a Laser Diode Driver is sent into a fiber delay line followed by a photodiode. the signal is filtered by a RF filter to select thedesired frequencyfollowed by amplifier and phase shifter then fed back into a Laser Diode Driver.

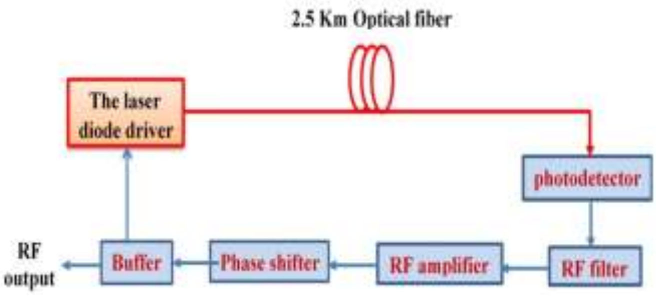


**Fig. 3.3**

The setup of the basic OEO is shown in Fig. 3.4

**Fig. 3.4**

The output of a basic scheme OEO from the spectrum analyzer is shown in Fig. 3.5

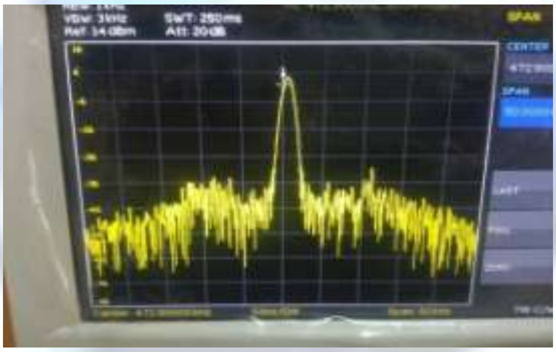


**Fig. 3.5**

From the above figure we can calculate the quality factor;
Q1= 472000Hz / 20 = 23600
The phase noiseof a basic scheme of the OEO [3] from the spectrum analyzer is shown in Fig. 3.6

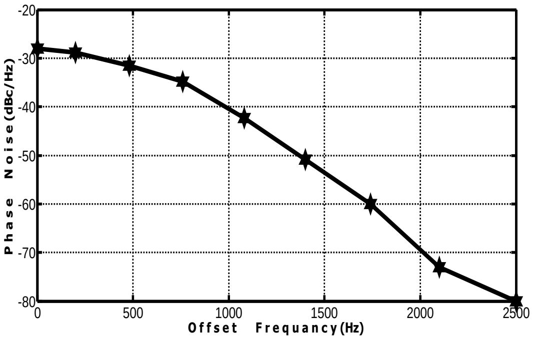


**Fig. 3.6**

### 3.2.2. Optical resonator OEO

It is interesting to use a compact resonator [4] and forget a too long and temperature sensitive optical delay line as shown in Fig. 3.7

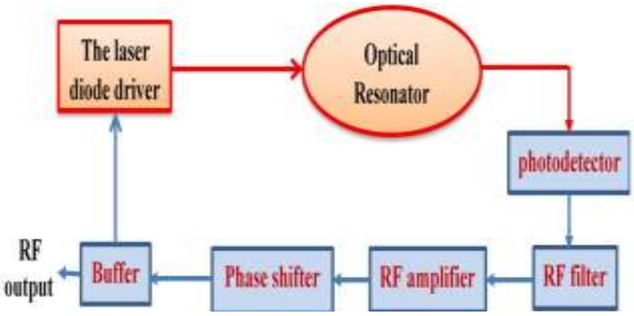


**Fig. 3.7**

The setup of the Optical resonator OEO is shown in Fig. 3.8

**Fig. 3.8**

The output of an Optical resonator OEO from the spectrum analyzer is shown in Fig. 3.9

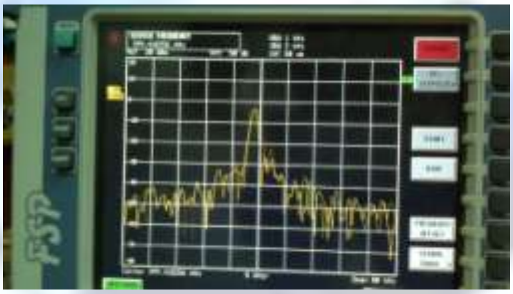


**Fig. 3.9**

From the above figure we can calculate the quality factor;
Q2= 400000Hz / 15 = 26667

The phase noiseof an Optical resonator OEO from the spectrum analyzer is shown in Fig. 3.10

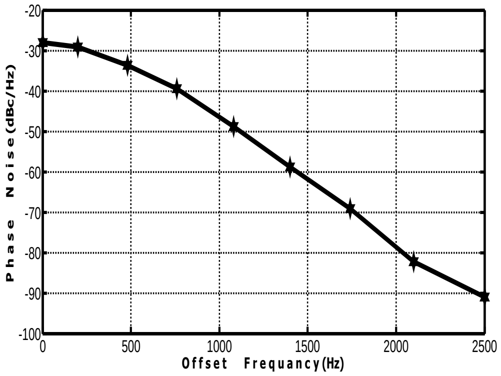


**Fig. 3.10**

### 3.2.3. Double loop OEO

In the OEO,the RF filter is not able to filter out many of the unwanted modes. Double loop OEOs [5] were reported, which suppress the unwanted modes by adding a second loop in the cavity. As shownin Fig. 3.11

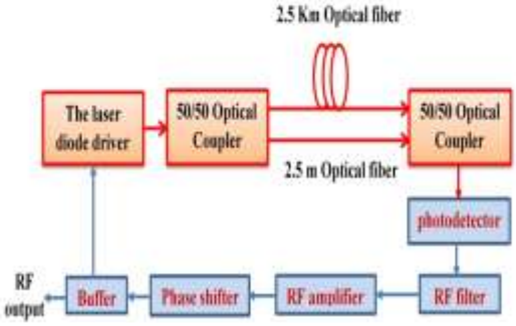


**Fig. 3.11**

The setup of the Double loop OEO is shown in Fig. 3.12

**Fig. 3.12**

The output of aDouble loop OEO from the spectrum analyzer is shown in Fig. 3.13

**Fig. 3.13**

From the above figure we can calculate the quality factor;

Q3= 410000Hz / 15 = 27333

The phase noiseof an Optical resonator OEO from the spectrum analyzer is shown in Fig. 3.14

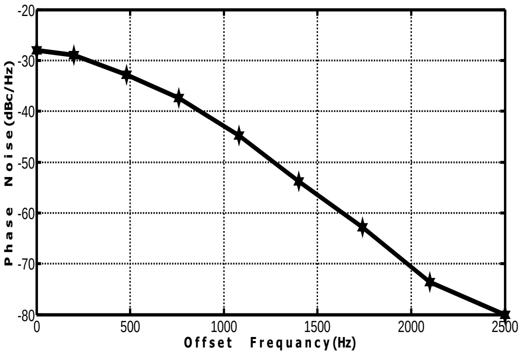
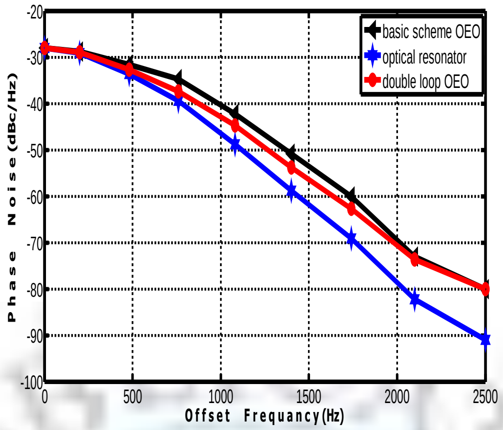


**Fig. 3.14**

### 3.2.4. Comparison of the phase noise results

Comparing the phase noise results show that the optical resonator OEO setup gives the best results because the remove of long and temperature sensitive optical delay line followed in preference the double loop OEO as result of suppress the unwanted modes by adding a second loop in the cavity as shown in Fig. 3.15



## Conclusion

The Optoelectronic oscillator has successfully achieved Avery stable high quality factor and low phase noise RF signal for different topologies(Basic scheme OEO, Optical resonator OEO, and Double loop OEO).The Optoelectronic oscillators have been proved better than an electronic oscillator with an electrical delay transmission line since they are less costly, less bulky, less losses and no electromagnetic interference.

## References

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