RF Assisted Absolute Phase Control of Semiconductor Lasers

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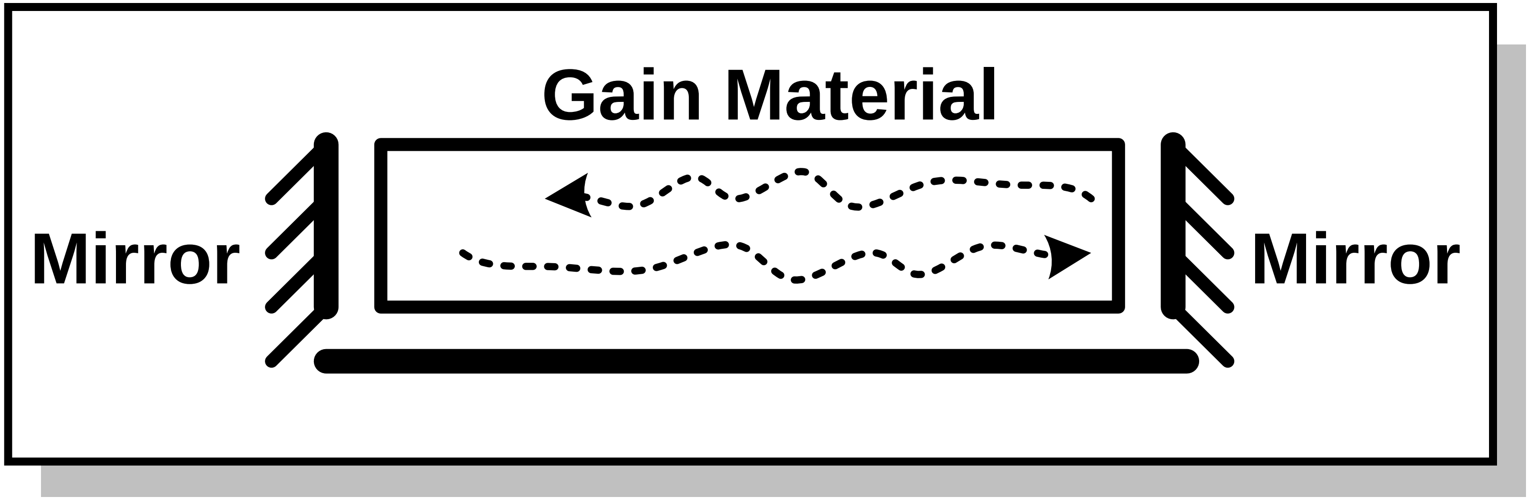
Semiconductor Laser



$$E(t) = E_0 e^{j(\omega_o t + \phi(t))}$$

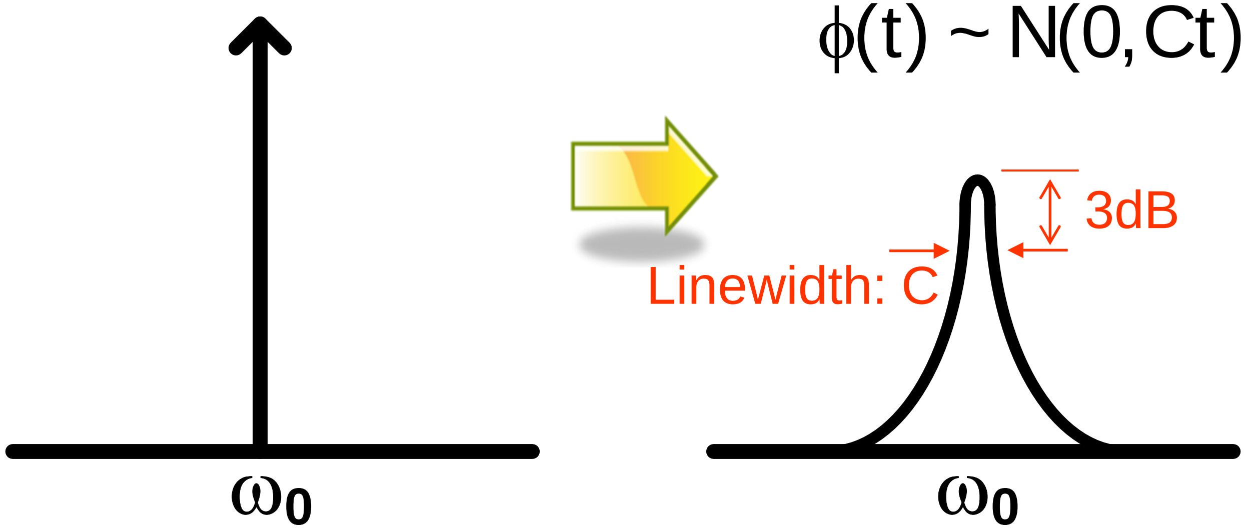
Laser is a very high frequency sinusoidal oscillator (200THz @ l=1550nm).

The Laser Frequency Spectrum

$$E(t) = E_0 e^{j\omega_0 t}$$

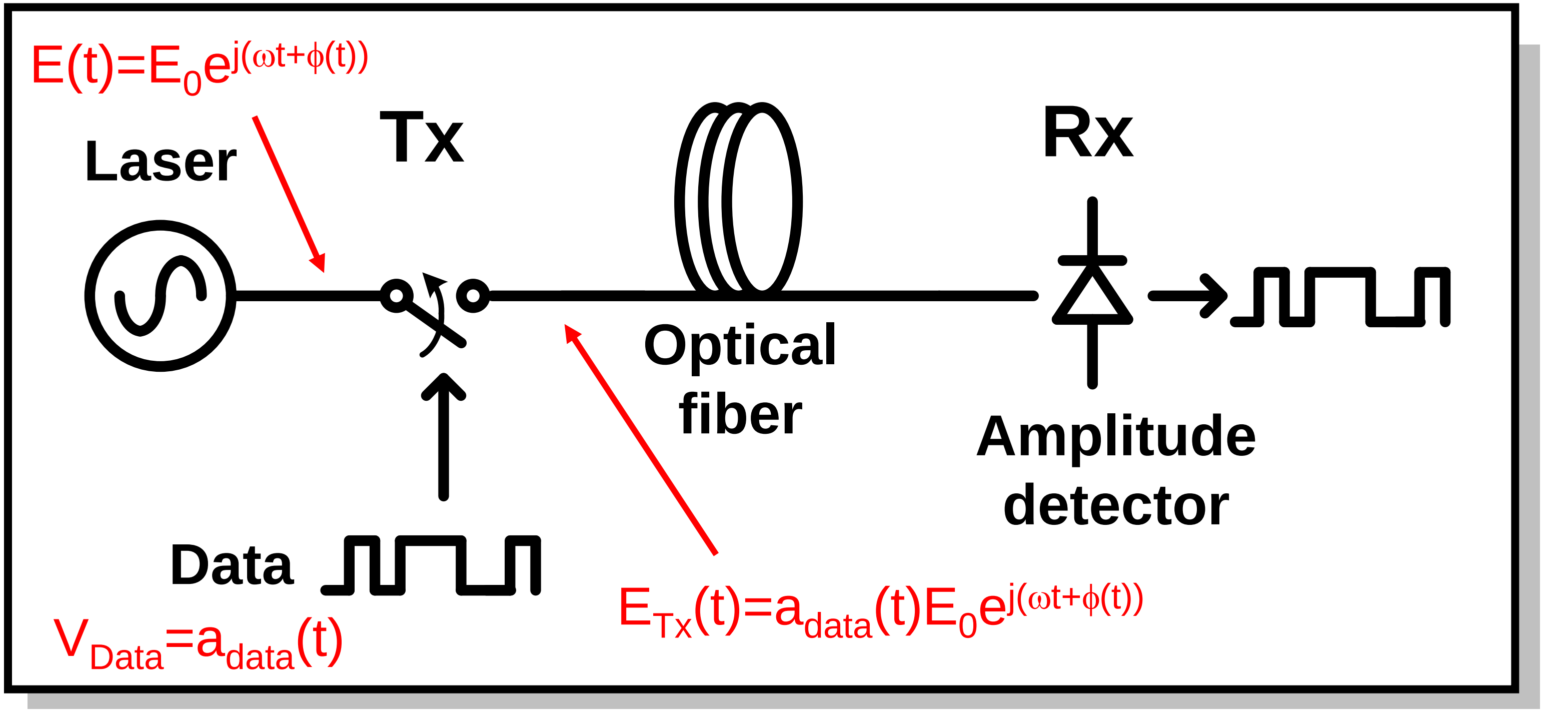
$$E(t) = E_0 e^{j(\omega_0 t + \phi(t))}$$

$$\phi(t) \sim N(0, Ct)$$



Laser noise in phase is a Wiener Process that results in a Lorentzian spectrum. Narrower spectrum corresponds to lower noise in phase.

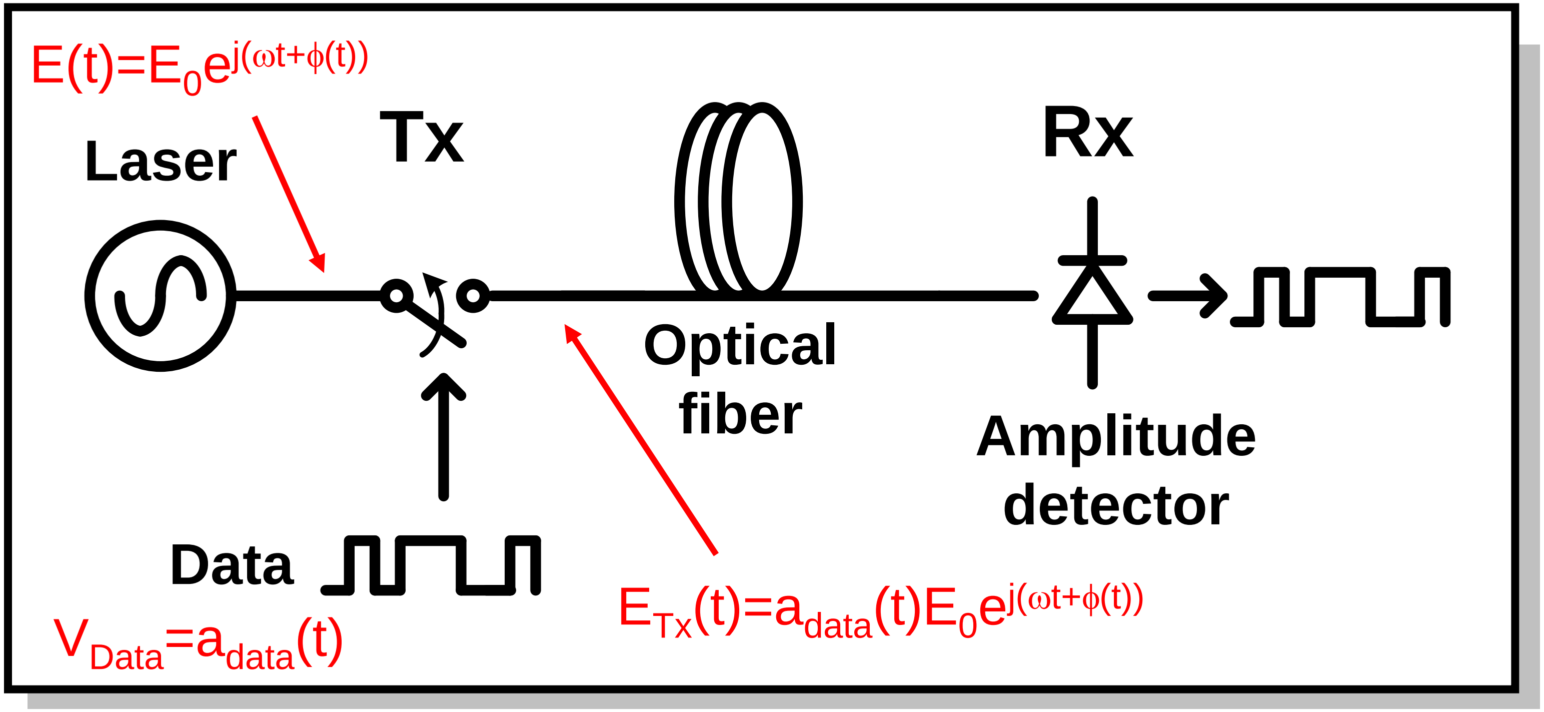
Optical Communications



$$E(t) = a_{data}(t)E_0e^{j(\omega_o t+\phi(t))}$$

Conventionally, only the light amplitude (intensity) is modulated.

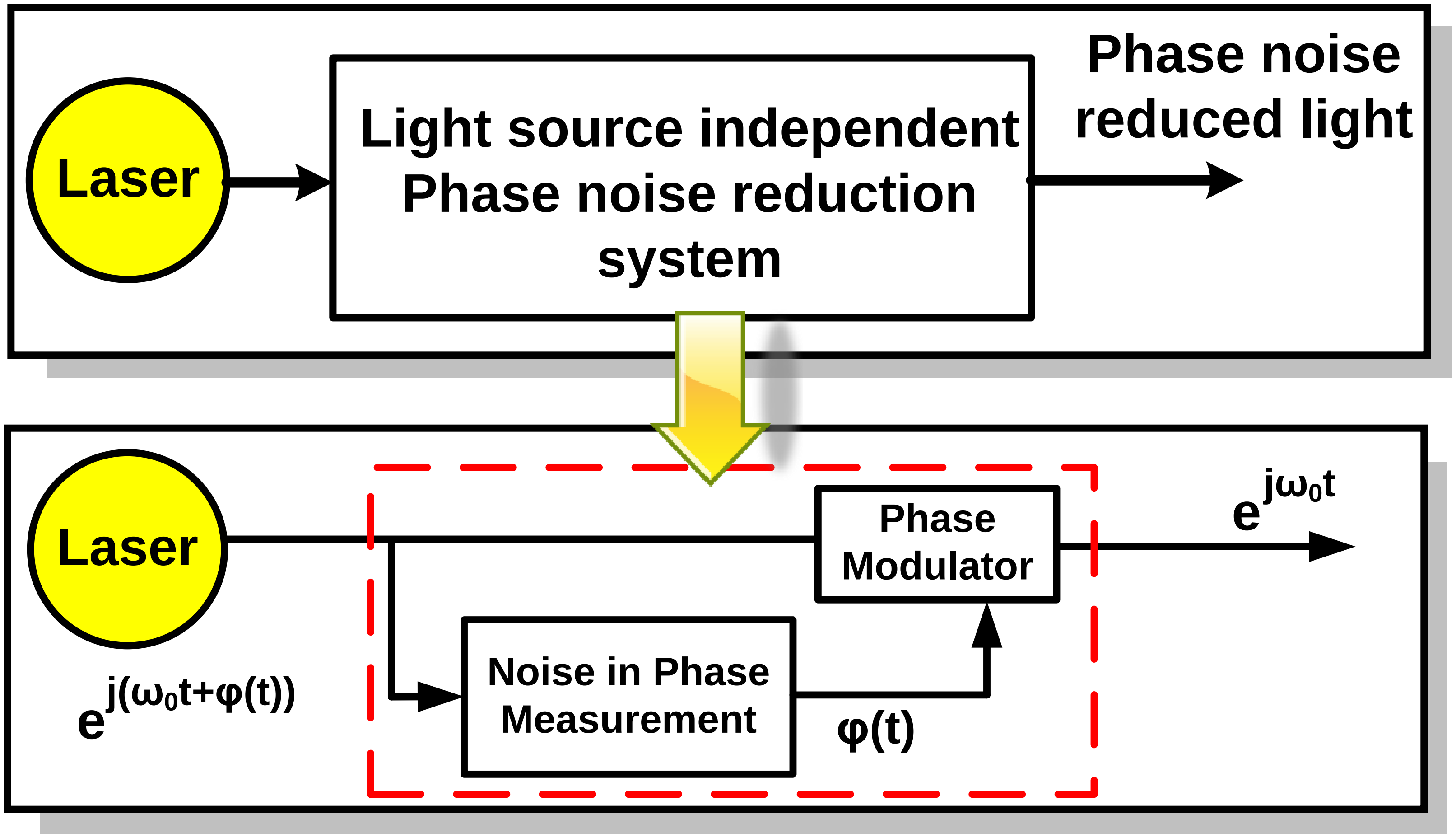
Optical Communications



$$E(t) = a_{data}(t) E_0 e^{j(\omega_o t + \phi(t) + \theta_{data}(t))}$$

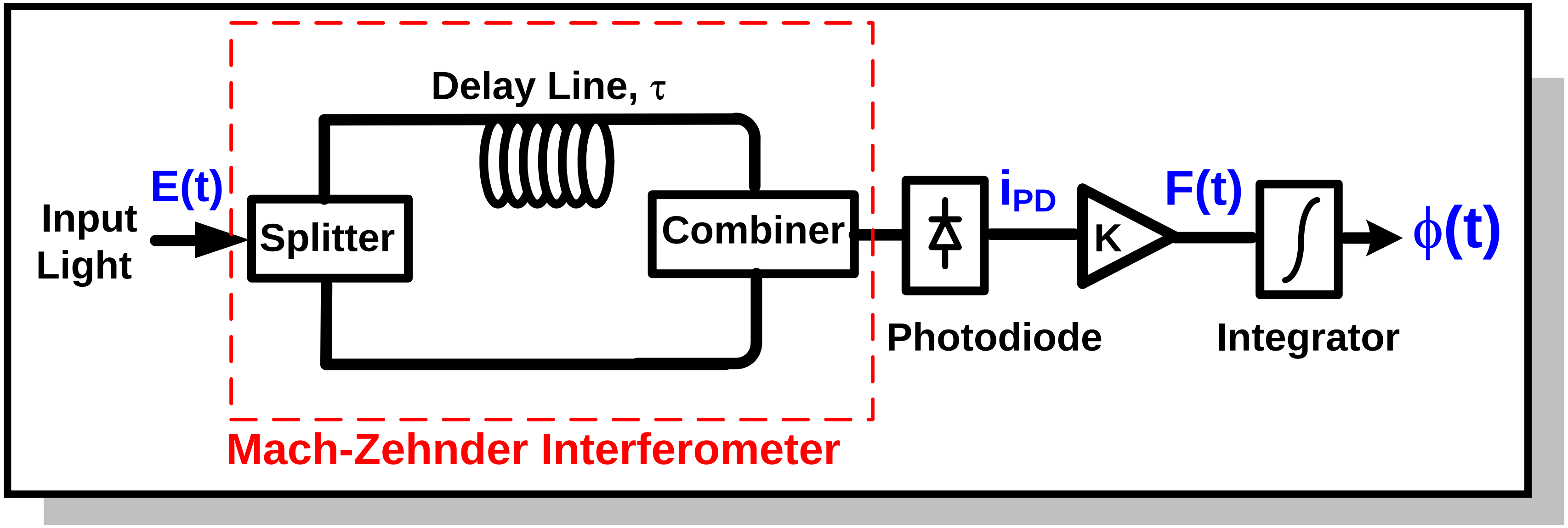
Laser phase modulation can be done if the laser noise in phase is small.

Feed-Forward Linewidth Reduction (FFLR)



Basic Idea: measure the laser noise in phase and subtract it from the laser's phase in a feed forward configuration.

Phase Noise Measurement System



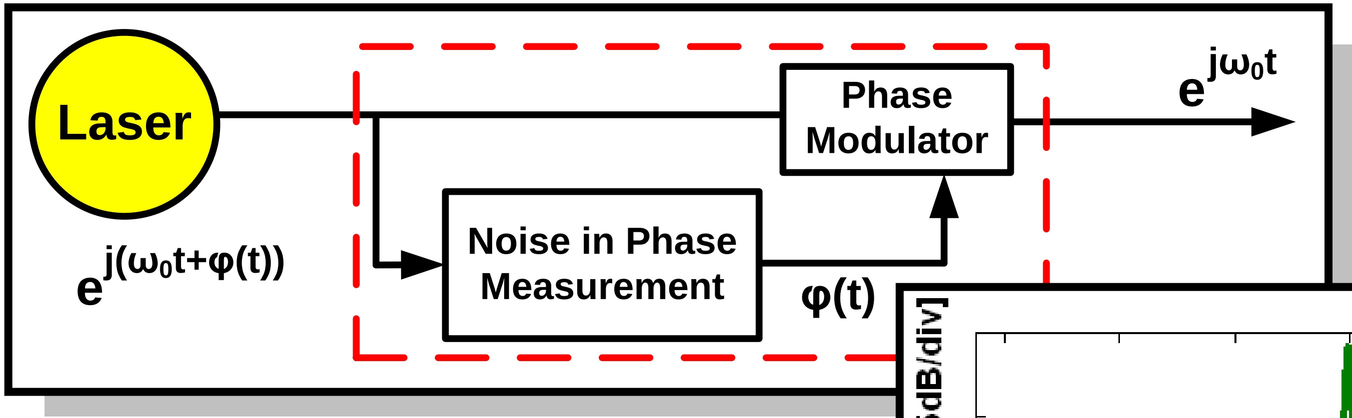
R: Photodiode responsivity, τ: The delay difference between two arms

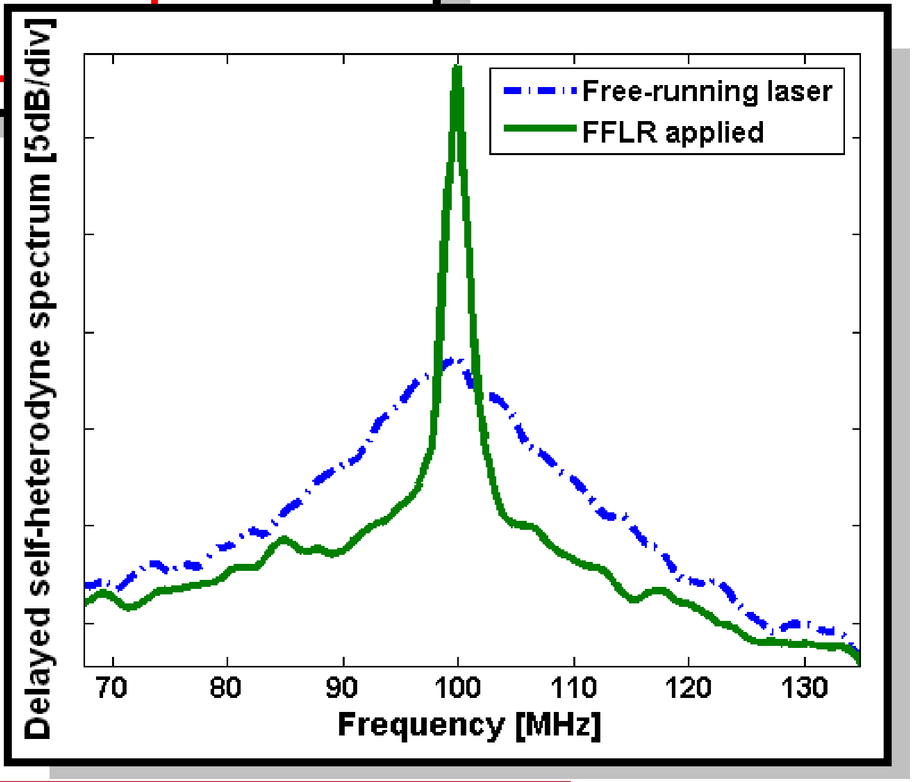
$$E(t) = \sqrt{P_o}\, e^{j(\omega_o t + \phi(t))} \Rightarrow i_{PD,ac} = \frac{1}{2} R P_o \cos(\omega_o \tau + \phi(t+\tau) - \phi(t))$$

$$\left.\begin{array}{r} \omega_o \tau = \dfrac{\pi}{2} \\ \phi(t+\tau) - \phi(t) \text{ is bounded} \end{array}\right\} \Rightarrow i_{PD,ac} \approx \frac{1}{2} R P_o \tau \frac{d\phi(t)}{dt}$$

$$K = \frac{2}{R P_o \tau} \Rightarrow F(t) = \frac{d\phi(t)}{dt}$$

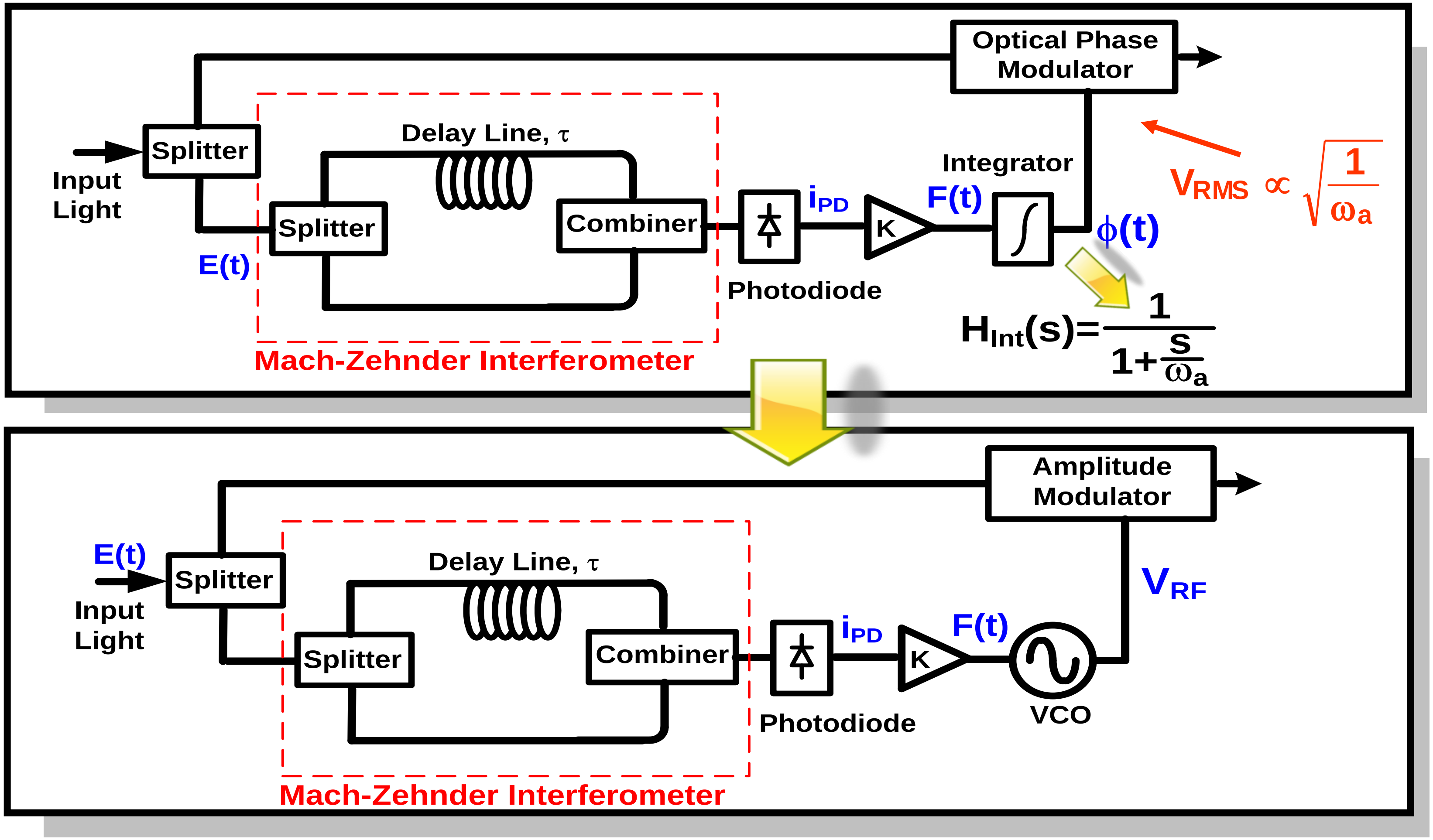
FFLR Implementation





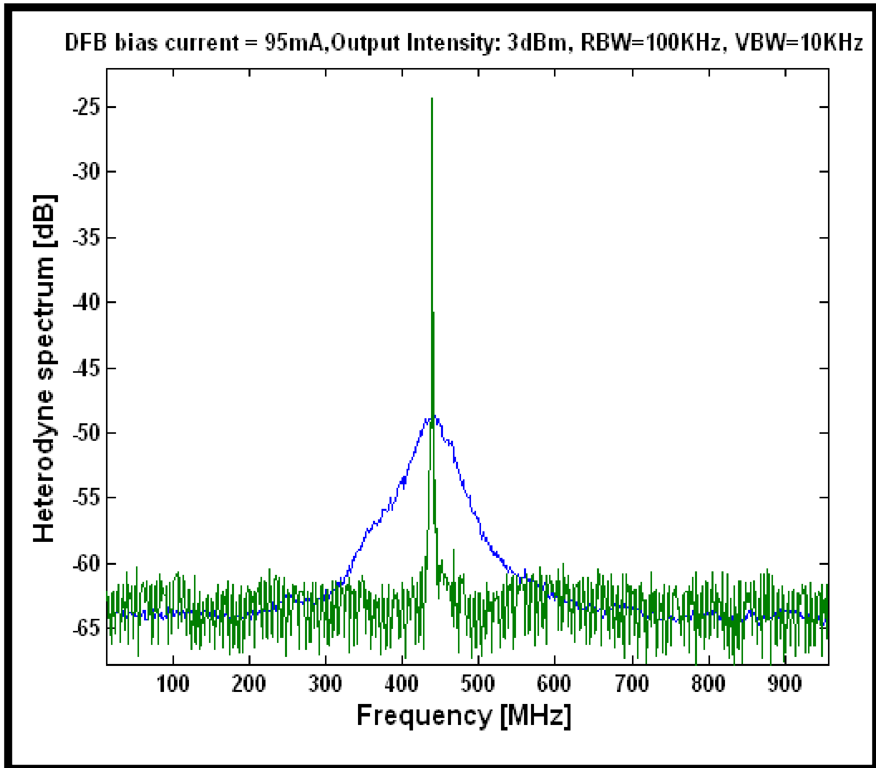
The laser phase noise is reduced by 10X.

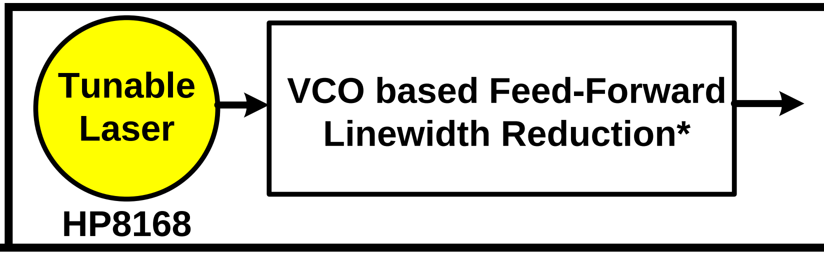
Voltage Swing Limitation

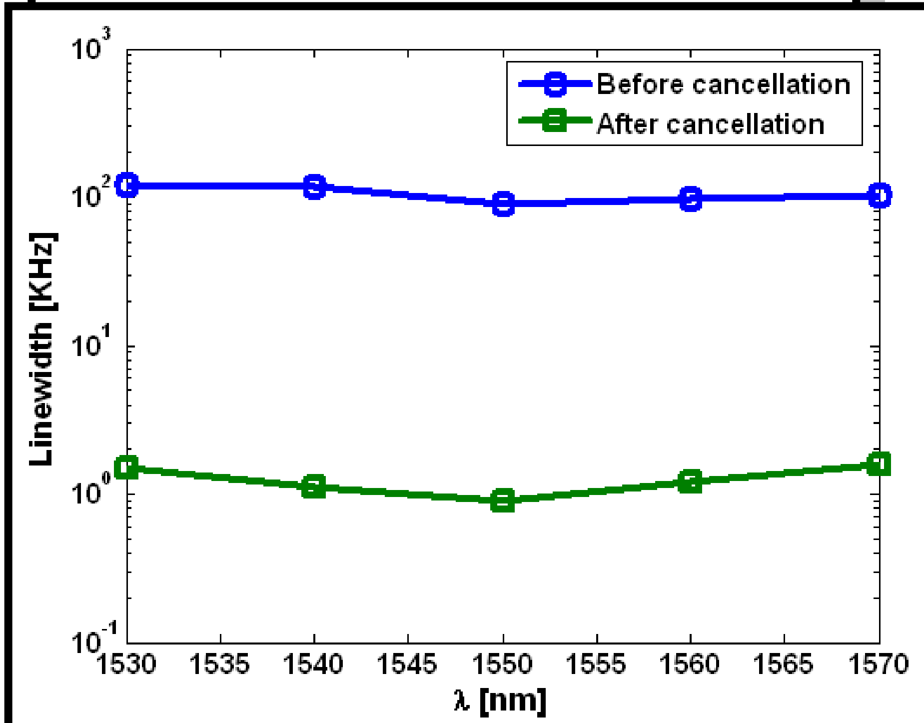


Maximum allowable voltage level at the input of the optical phase modulator limits the low operating frequency of the integrator.

Measurements



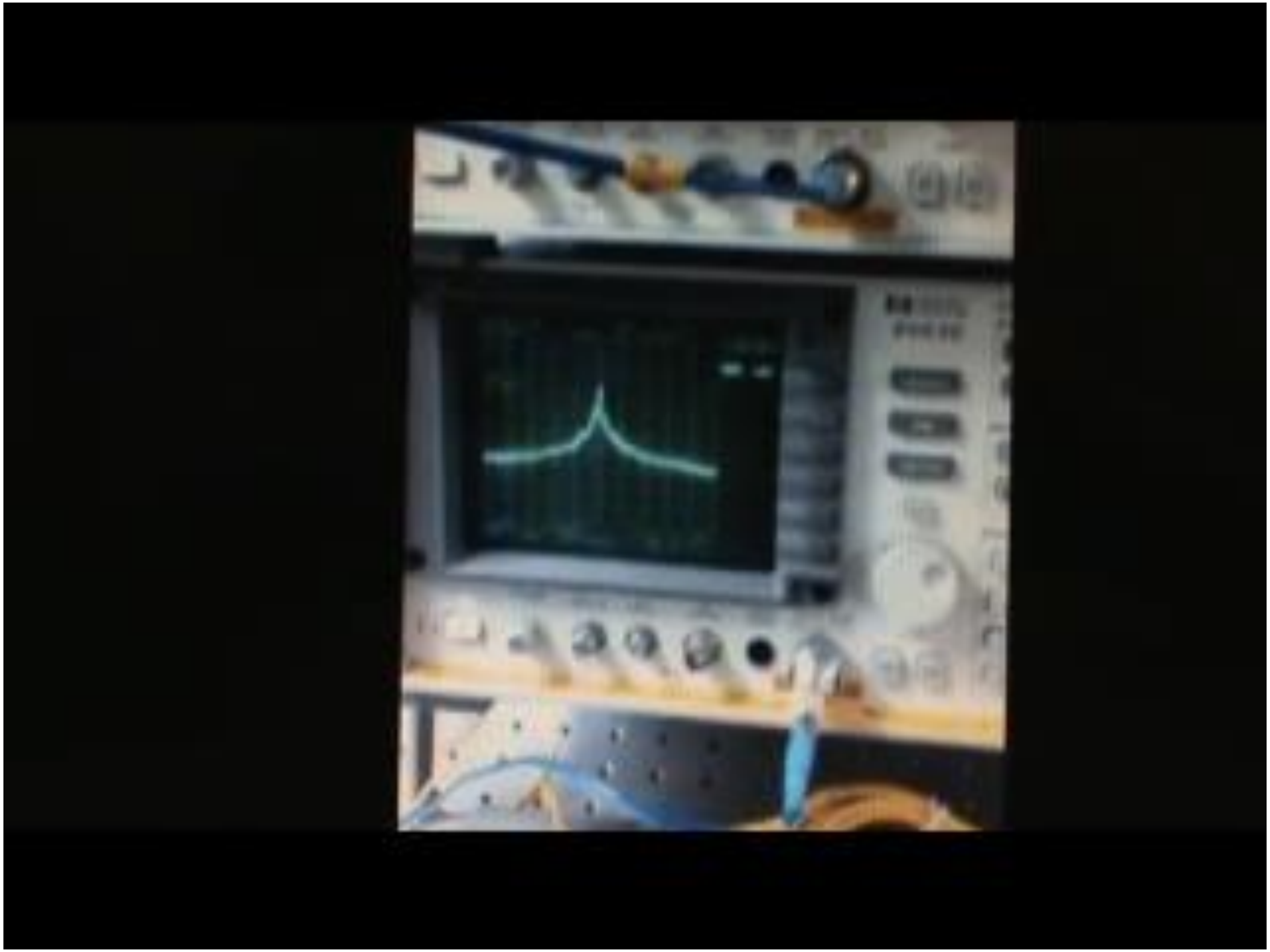




Linewidth is reduced from 7.5MHz to 1.8KHz.

By placing the proposed phase noise cancellation system after a tunable laser, an ultra narrow linewidth tunable light source can be realized.

Feed-Forward Linewidth Reduction in Action



Conclusion

- **Absolute phase control of semiconductor laser is demonstrated where the Feed-Forward Linewidth Reduction (FFLR) scheme has been implemented and linewidth reduction from 7.5MHz to 1.8KHz has been measured.**

- **By placing the proposed phase noise cancellation system after a tunable laser, an ultra narrow linewidth tunable light source can be realized.**