# RF Photonics Research

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## The Optoelectronic Oscillator

The optoelectronic oscillator (OEO) is a promising low phase noise radio frequency (RF) source due to the high-*Q* provided by low-loss optical fiber delay lines. At ARL, we have designed and constructed a dual injection-locked OEO (DIL-OEO) that can generate spurious-mode-free low phase noise sources at frequencies from 1-40 GHz.

The DIL-OEO can be used as a low noise source in antenna remoting, phased array antenna, and secure communications systems. The DIL-OEO can also be used to synchronize several devices by transmitting a master signal over optical fiber in the absence of GPS.

To reach its full potential, we must investigate all potential sources of phase noise and frequency instability in the DIL-OEO. We also must study the effects of transmitting low-phase noise RF signals over optical fiber.

## Component Level Needs

Minimize phase noise
Improve system stability
Reduce degradation from RF interference
Actively suppress thermal and vibration effects

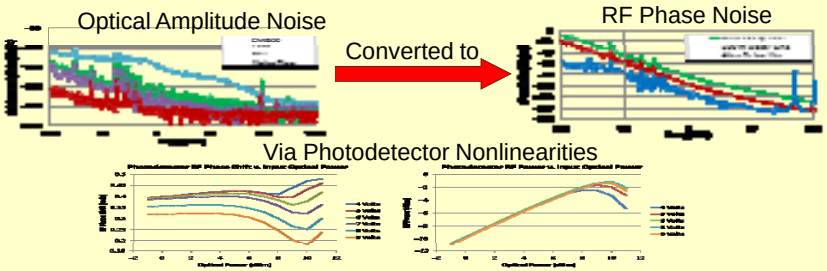
***Summary of Salient Noise Sources***

| Physical Effect | Type |
|---|---|
| Electronic (amps, PDs) | |
| Shot noise | A, F, NL |
| Thermal noise | A, NF, NL |
| near-DC + up-conversion | M, F+NF, NL |
| Optical (lasers, fibers) | |
| Laser noise | |
| Laser noise | M, OE, NL |
| Laser noise+ dispersion | M, OE, L |
| Laser noise + Kerr nonlinearity | M, OE, L |

| Physical Effect | Type |
|---|---|
| Double-scattering processes | |
| Rayleigh (elastic) | M, F, L |
| Brillouin (inelastic) | M, F, L |
| Raman (inelastic) | M, F, L |
| Reflection from isolators, and couplers | M, NF, L |
| Environmental effects | |
| Temperature fluctuations | M, NF, L |
| Vibrations | M, NF, L |
| Polarization mode dispersion | M, NF, I |

**TYPES**:
A: additive, M: multiplicative, F: fundamental, NF: non-fundamental or environmental, OE: opto-electronic, L: fiber-length dependent, NL: non-length dependent

## System-Level Device Interactions



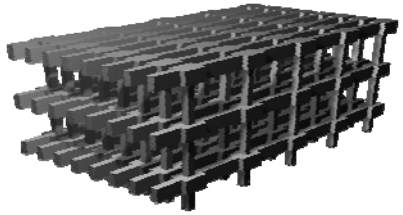

## "Slow-light" low loss Waveguide

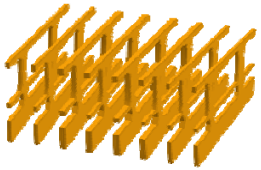
It is highly desirable have fiber like ultra-low loss semiconductor waveguide that also has tunable high Q time delay capability therefore RF-Photonic system such as OEO, phase array antenna, RF-Photonic correlation receiver, tunable filter, etc can be made by chip scale integrated circuits.

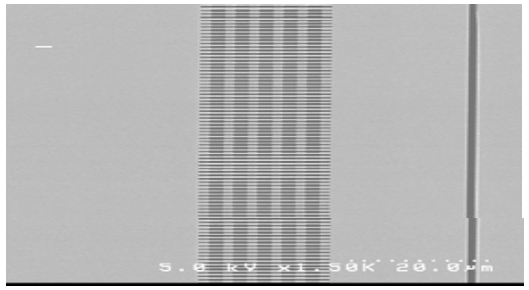
The goal is to develop a Si based photonic crystal hollow-core waveguide that has high dispersion property ("slow light") with tunability and at same time has very low waveguide loss. Traditional semiconductor waveguide can not achieve this goal due to the Kramers-Kronging relation, therefore we have to search new structures such as nano-scale photonic crystal, high-contrast grating, meta material, etc to build the waveguide /cladding

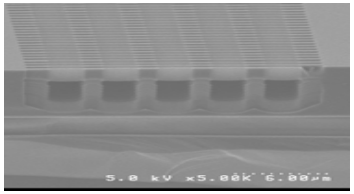
## New Fabrication Technique

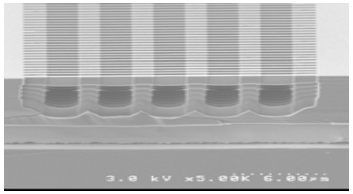
ARL RF-Photonics team has developed a new a simplified three-dimensional (3D) Photonic Crystal (PhC) fabrication technique that can be used to fabricate a nanoscale 3D structure from the two dimensional (2D) surface of a silicon (Si), or silicon on insulator (SOI) wafer using a single modified Bosch plasma etching process. Using this technique, we demonstrated such a hollow-core PhC waveguide-array structure.











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