

**Title:**

Focusing light in space and time

**Abstract:**

Redirecting and focusing light in space is basic technology behind eyeglasses and telescopes. The optical elements -- lenses or mirrors -- are static on the time scale relevant to the waves and thus do not change the color (frequency) of the waves.

What if the optical elements were allowed to change in time, fast? Now frequency can change (Doppler effect), but more interestingly, it becomes possible to focus waves not only in space but also in time, with the energy compressed in short pulses. This is the physics underlying pulsed lasers, capable of generating femto-second short pulses.

In lasers, external pumping (gain) is required in order compensate for significant losses typical of an active optical medium. In contrast, in microwave regime, by using superconducting resonators it is possible to dramatically suppress losses, with the cavity finesse reaching billions. In combination with superconducting qubits, this enables new quantum information storage and manipulation techniques. Rapid periodic variation of parameters, similar to pulsed lasers, is also possible. We show that in this nearly lossless regime, short pulses can be generated *without externally provided gain*. Such manipulation can be used to temporally compress and decompress signals and create highly entangled quantum states of photons.

When starting from quantum vacuum, parametric pumping can focus zero-point fluctuations into pulses, while depleting them elsewhere. Such exotic light focusing can be interpreted in terms of emergent space-time metric that contains event horizons.

**Refs:**

Ivar Martin, Annals of Physics Volume 405, June 2019, Pages 101-129

Z. Huang, A. Clerk, I. Martin, unpublished (2019)

**Biosketch:**

Ivar Martin got his B.S. in Physics from Moscow State University. For his PhD (at UIUC) he worked on disordered interacting systems. He then spent 13 years at Los Alamos National Lab, first as a postdoc, and then as a staff member. Since 2013 he has been at Argonne National Laboratory. His interests include physics of materials as well as problems of nonequilibrium and driven quantum systems.