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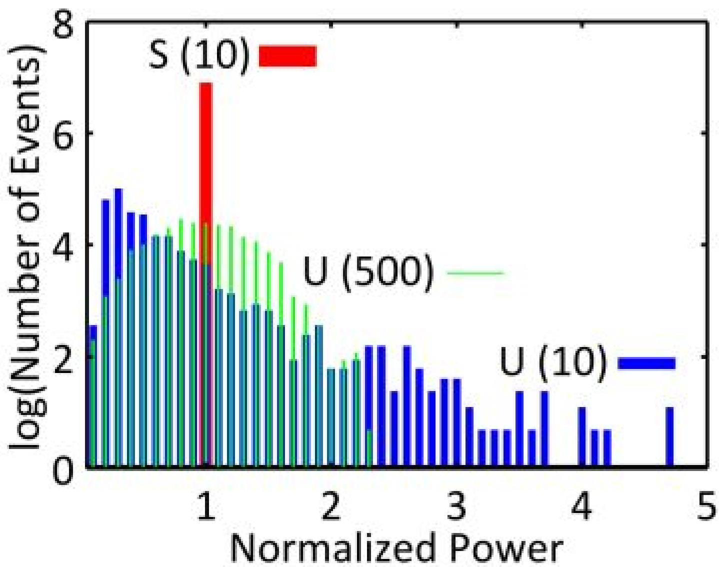
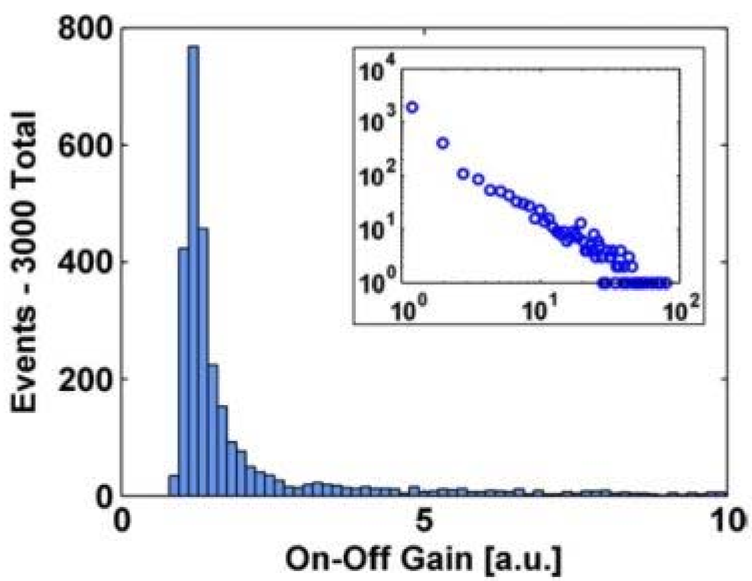
Silicon photonics goes rogue

Rare events found in compact nonlinear optical systems.



(http://images.iop.org/objects/jio/labtalk/4/5/15/Image1.jpg)
Distribution of power in spontaneous supercontinuum generation (http://images.iop.org/objects/jio/labtalk/4/5/15/Image1.jpg)



(http://images.iop.org/objects/jio/labtalk/4/5/15/Image2.jpg)
Dependence of Stokes gain in stimulated Raman amplification (http://images.iop.org/objects/jio/labtalk/4/5/15/Image2.jpg)

Rogue events are statistically rare but carry a huge impact. Occurring in everyday contexts such as finance, network traffic, ocean waves and elsewhere, their extreme properties are virtually precluded by the exponentially decaying tails of the normal distribution. They instead follow heavy-tailed statistics, which arise from a nonlinear dependence on initial conditions. For example, nonlinearity can transform a Gaussian input into a heavy-tailed output. Attempts to discern the causes and probabilities of extreme events are hampered by their scarcity and by difficulty in performing controlled experiments. Research into generation of rare events in nonlinear optics has accelerated recently due to the discovery of optical rogue waves in optical fibers. This experimental platform enables researchers to study and stimulate rogue processes in a controlled environment and collect voluminous data.

As described in DeVore *et al* 2013 *J. Opt.* 15 064001 (http://iopscience.iop.org/2040-8986/15/6/064001/article) , researchers have also discovered two nonlinear optical silicon systems that result in rare flashes of bright light. In one system, launching intense pulses into silicon waveguides results in supercontinuum generation—strong nonlinear optical broadening due to a host of complex interactions. The broadband gain of modulation instability (an integral part of supercontinuum) results in sensitivity to noise well separated from the input spectrum. This complex mixing of frequencies occasionally results in especially strong broadening, yielding heavy-tailed distribution from what was once Gaussian noise. By stimulating the initial conditions with a well-chosen seed, the broadening can be controlled and stabilized.

In the other silicon system, extreme behavior is observed in stimulated Raman scattering due to in-band pump fluctuations. Theory predicts that a noisy pump following normal statistics is transformed via exponential stimulated Raman gain into a power-law dependence of Stokes gain. Results from experiments match exceedingly well for Stokes and anti-Stokes pulses (the latter from coherent anti-Stokes Raman scattering).

Enhancing our understanding of noise-driven nonlinear processes in silicon photonics unveils winner-takes-all behavior that also appears in biological, financial and socioeconomic contexts.

More details (http://iopscience.iop.org/2040-8986/15/6/064001/article) from the authors on this work are published in a special issue of *Journal of Optics* dedicated to optical rogue waves.

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