Linear Optical Rogue Waves in Disordered Photonic Networks

Marios Mattheakis

University of Crete

Collaborators: I.J. Pitsios, G.P. Tsironis, S. Tzortzakis
Outline

➢ Rogue (or Freak) waves
➢ Luneburg and inverted Luneburg lens
➢ Simulation and Experiment setup
➢ Linear optical rogue wave
➢ Rogue wave as strong scattering effect
➢ Nonlinearity in linear rogue wave
➢ Conclusion
Rogue Waves

• Rogue waves are spontaneous events which are defined as waves whose height is more than twice the significant wave height (SWH)

• SWH is defined as the mean of the largest third of waves in a wave record

• Firstly observed in 1995 in oceanic surface waves

Artistic illustrator of oceanic rogue waves
Rogue Waves in Optics

- R. Hohmann et al. have observed experimentally optical rogue waves in microwave regime.
- They study the microwave transport through a scattering system composed of randomly placed metallic cones.

A Luneburg lens is a spherical structure with a specific functional dependence on the lens radius (Eq. 1).

Its basic property is that it focuses parallel rays on the spherical surface on the opposite side of the lens.

An inverted Luneburg lens has the opposite characteristics (Eq. 2).

\[ n(r) = \sqrt{2 - \left(\frac{r}{R}\right)^2} \]  

\[ n(r) = \sqrt{1 + \left(\frac{r}{R}\right)^2} \]
Simulation and Experiment setup

- A number of inverted Luneburg lens network, where constructed in the bulk of glass plates forming a lattice. By allowing a laser beam to propagate through these lattices we could monitor the occasion of freak wave.

- Simulations have been performed in 2D lattices

- Experiments have been performed in 3D lattices

Both in simulations and in experiments the beam propagates in z axis
Linear Rogue Wave (simulation)
Distribution of Intensities

- Rayleigh distribution for the propagation through a random media
  \[ P(I) = e^{-I} \]
  - \( I \) is the intensity normalized to one

- Long tails implies rogue waves
Linear Rogue Wave (experiment)
Refractive index variation (simulations)

- Generalizing the refractive index by introducing a “strength” factor $\alpha$, which is proportional to refractive index variation

$$n(r; \alpha) = \sqrt{2 + \alpha \left( \frac{r}{R} \right)^2 - 1}$$
Refractive index variation (experiment)

- Changing lens refractive index the variation by controlling the irradiation energy that we construct the lenses.
- The irradiation energy is proportional to the refractive index variation

No Rogue waves for low refractive index variation, resulting that Rogue wave is a strong scattering effect.
Rogue waves in the non-linear regime (simulations)

- Introducing nonlinearity in the refractive index (Kerr effect)

\[ n(r)^2 = n_L^2 + \chi |E|^2 \]

- \( n_L \) is the linear part of refr. index
- \( E \) is the electric field

- Low nonlinearity does not affect the linear rogue wave
- In very high nonlinearity the rogue wave disappears
Rogue waves in the non-linear regime (experiment)

Rogue wave lattice below non-linear threshold

Rogue wave lattice above non-linear threshold

Non rogue wave lattice above non-linear threshold
Conclusion

- The experimental results, although in 3D lattices, are in perfect agreement with the numerics which are performed in 2D, further proving the advisability of this work.

- Rogue wave seems to be a purely **LINEAR** event

- We propose that Rogue wave is a strong scattering phenomenon

Thanks for attention

Email: mariosmat@physics.uoc.gr
website: http://nls.physics.uoc.gr

This research has been co-financed by the European Union (European Social Fund ESF) and Greek national funds through the Operational Program “Education and Lifelong Learning” of the National Strategic Reference Framework (NSRF) - Research Funding Program: THALES. Investing in knowledge society through the European Social Fund.