Soliton molecules and optical rogue waves

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Today's considerable world-wide data traffic would be unthinkable without fiber-optic cables which have emerged as the best-performing conduits for information. Some fundamentals about light guiding in optical fibers will be reviewed. The main difference to conventional electrical cables lies in the fact that fibers are a nonlinear medium: the index of refraction of the glass is intensity-dependent. While the index change is small, its implications are huge: A nonlinear wave equation governs the propagation of signals, and it has solutions with remarkable properties. Probably the best known example is the soliton, a light pulse of special shape which has the remarkable property that perturbations (as they may occur during propagation) can heal out. It will be discussed how the soliton concept can be used –and is being used– for commercial communication lines. This involves a particular type of fiber called dispersion-managed fiber.

Society demands an ever increasing amount of data to be transmitted around the clock. For a binary coding of data (pulse or no pulse) the data-carrying capacity of fibers is now nearly exhausted, and the search is on for suitable coding formats beyond binary. One possible way is interesting also from a fundamental-physics point of view: Solitons in dispersion-managed fibers can form bound states which propagate stably down the fiber, known as soliton molecules. Proof-of-principle experiments for quaternary data transmission using the soliton molecule format will be described.

There are other solutions of the nonlinear wave equation. They include the Akhmediev breather and the Peregrine soliton, both at the center of recent discussions about what is now called 'rogue waves': In remarkable deviation from standard probability distribution, water surface waves can rarely form peaks of extraordinary crest height which can wreak havoc for ships on the ocean. It has been pointed out that certain analogies to light pulses in fibers exist, and similar phenomena have been demonstrated in fibers. Some concepts of optical rogue waves will be discussed.

Recommended reading:

- Fedor Mitschke. Optical Fibers. Physics and Technology. Springer 2009
- Govind Agrawal. Nonlinear Fiber Optics, 5th edition. Academic Press 2013