get "arranged" at equal distances from one another.

We believe that these results on pattern formation in weakly-correlated nonlinear wave systems are just the tip of the iceberg, and that this subject offer many more exciting surprises. The importance, however of these issues is in the fact that such phenomena are universal. In principle, any nonlinear and disordered wave system in which the nonlinearity responds to some "ensemble average" should exhibit these features. For example, Bose Einstein Condensates, in which the ensemble average is manifested in keeping only head-on collisions in the nonlinear term, has pattern formation properties equivalent to our incoherent optical system.

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QThL4

5:45 pm

Pattern Formation of Spatiotemporal Modulation Instability of Incoherent Light and its Phase Transition

Chien-Chung Jeng and Ming-Feng Shih,
Department of Physics, National Taiwan
University, Taipei 10617, Taiwan, Email:
mfshih@phys.ntu.edu.tw

In self-focusing nonlinear media, modulation instability (MI) causes the uniform light beam to break up into periodic patterns since the noise, carried by the light, of certain spatial frequency gets amplified by the interplay between the diffraction and the self-focusing effect. Thus, when the light source is incoherent, the nonlinear effect must be above some threshold for MI to develop as incoherent light diffracts more.¹ The observation of incoherent MI has been done in noninstantaneous nonlinear media because it is preferred the nonlinearity not to respond to the very quick intensity fluctuation of incoherent light.² Recently, we observe that the MI patterns of coherent light actually comes from time-varying random noise rather than from a static noise.³ The evidence is that the MI patterns of coherent light can move, and the moving rate depends on the response time of the material's nonlinearity. We then suspect similar spatiotemporal MI of incoherent light can also happen. Indeed, we observe the spatiotemporal MI of incoherent light, and even to our surprise, we observe that the MI patterns change from one periodicity to another periodically abruptly at certain critical nonlinear-

QThL4 Fig. 1. The intensity structure (a) at the input face of the crystal when the diffuser is still and (b)–(g) at the output face of the crystal when the diffuser is rotating and taken at 20 seconds apart. The dashed circles, added manually, indicate the moving pattern.

ity strength or spatial coherence of the light, indicating a first order phase transition.

We pass a CW laser light ($\lambda = 532 \text{ nm}$) through a fast rotating diffuser and control the spatial coherence of the light by adjusting the diameter of the laser beam incident on the diffuser. This partially incoherent and extraordinarily polarized beam is collimated and launched, along the crystalline a -axis, into a biased photorefractive SBN crystal ($a \times b \times c = 5 \text{ mm} \times 10 \text{ mm} \times 5 \text{ mm}$, $n_0 = 2.35$, and $r_{33} = 245 \text{ pm/v}$), that acts as the noninstantaneous self-focusing medium.¹ The correlation distance l_c of this partially incoherent light is

QThL4 Fig. 2. The picture of intensity structure taken at the output face of the crystal under different biasing voltage. The input speckle size is about $65 \mu\text{m}$. (c)–(e) are taken 50 seconds apart.

estimated by the averaged speckle size. To observe the pattern formation of spatiotemporal MI, we first adjust the averaged speckle size of the light beam (intensity $\approx 31 \text{ mW/cm}^2$) to be about $65 \mu\text{m}$ [Fig. 1(a)] and apply a voltage about 1.2 kV on the SBN crystal with the polarity against the crystalline c -axis. After the MI pattern forms and reaches a steady state, we then take the pictures of the patterns every 20 seconds [e.g. Fig. 1(b) ~ (g)] and find the pattern gradually changes and never stops. We believe such moving patterns of spatiotemporal MI may result from the time-varying intensity noise, of the part that is slow

QThL4 Fig. 3. The picture of intensity structure taken at the output face of the crystal under different speckle size. (f)–(h) are taken at 40 seconds apart. (j) and (k) are taken at different time.

enough to be caught up by the SBN crystal, whose response time is about a few tens of seconds at our experimental optical intensity.

We then try to study how the nonlinearity strength affects the spatial period of the MI pattern. We tune the biasing voltage from 0.63 kV to 1.5 kV and expect the period to decrease as a result of increased nonlinearity. To our surprise, instead of observing a continuous change of the period, we observe an abrupt change of the period when the voltage is around 0.93 kV. The pattern [Fig. 2. (c)] shows a coexistence of a domain of long period similar to that of 0.83 kV [Fig. 2.(b)] and a domain of short period similar to that of 1.2 kV [Fig. 2(f)], indicating a first order phase transition. The domains also gradually move [Fig. 2. (c)–(e)] because of the slow part of the time-varying intensity noise.

Since MI is an interplay between diffraction and self-focusing effects, we guess that, if we keep the nonlinearity strength unchanged but vary the spatial coherence, (smaller speckle size meaning less coherent light and larger diffraction effect) we would observe similar phase transition behaviors. We then set the biasing voltage at 0.93 kV and the optical intensity at 28.5 mW/cm² and change the speckle size from 24 μm to 240 μm . Figure 3 shows two critical points of phase transition. When the speckle size is around 67 μm , Fig. 3. (f)–(h) shows a coexistence of a domain of long period similar to that of 60 μm [Fig. 3.(e)] and a domain of short period similar to that of 93 μm [Fig. 3(i)]. When the speckle size is around 115 μm , Fig. 3(j)–(k) shows the transition from the 1D MI pattern similar to that of 93 μm [Fig. 3(i)] to the 2D MI pattern similar to that of 140 or 240 μm [Fig. 3(l), (m)]. Also notice that when speckle size is at 24 μm [Fig. 3(a)], MI patterns does not appear, confirming the threshold behavior reported by Ref. 1.

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QThL5

6:00 pm

Interactions of Discrete Solitons with Defects and Interfaces

R. Morandotti, H.S. Eisenberg, D. Mandelik and Y. Silberberg, Department of Physics of Complex Systems, Weizmann Institute of Science, Rehovot, Israel, 76100, Email: ferober@wisEmail.weizmann.ac.il

D. Modotto and M. Sorel, Department of Electronics and Electrical Engineering, University of Glasgow, Glasgow, Scotland, G12 8QQ

J.S. Aitchison, The Edward S. Rogers Sr. Department of Electrical And Computer Eng., University of Toronto, Toronto, ON, M5S 3G4

Nonlinear discrete dynamics has recently attracted a lot of interest, due to its generality and peculiarity. Systems of different sizes and nature

QThL5 Fig. 1. Interaction of a large beam with a large repulsive defect (interface between two arrays). At low power (a) the field accumulate on one side of the defect before beam tunneling takes place at large angles. For higher power (b), the tunneling is preceded by a significant reflection of the discrete soliton.

share the same dynamical nonlinear properties, and can support stable energy localizations. Those localizations, named discrete solitons, can interact both among them and with the structure in which they propagate. A particular class of optical discrete solitons, propagating in arrays of nonlinear waveguides, has been convenient for experimental studies of this phenomenon. These solitons are similar to continuous optical solitons, and like those, they can be generated in media through the Kerr nonlinearity. Unlike continuous spatial solitons, they do not have the translation and rotation symmetry, and therefore exhibit a number of novel dynamical properties.

Theoretical studies have predicted that soliton reflection, transmission and trapping can be induced by inserting suitable defects in an array. Several switching configurations and applications can be designed by slightly modifications of the geometry of the array.

In this work we study experimentally the interaction of discrete solitons with structural defects in arrays of AlGaAs waveguides. We fabricated both attractive and repulsive defects in otherwise uniform arrays. When a beam is injected in proximity of a defect, little difference is observed between attractive and repulsive defects, as they reflect and transmit the beam accordingly to its transverse velocity. However, when the beam is injected at the defect, trapping takes place in the attractive defect, while the repulsive defect is very unstable and drives the soliton away. We will present a series of different experimental situations, supported by the correspondent numerical analysis.

QThL6

6:15 pm

Collisions Between Discrete Vector Solitons

Mark J. Ablowitz and Ziad H. Musslimani, Department of Applied Mathematics, University of Colorado at Boulder, Boulder, CO 80309-0526

Recently, there has been considerable interest in the study of discrete spatial solitons in nonlinear media. Such solitons are localized modes of nonlinear lattices that form when discrete diffraction is balanced by nonlinearity. Discrete solitons have been demonstrated to exist in a wide range of physical systems. An array of coupled optical

waveguides is a setting that represents a convenient laboratory for experimental observations. The first theoretical prediction of discrete solitons in an optical waveguide array was reported in¹ and was later experimentally observed in². When a low intensity beam is injected into one or a few waveguides, the propagating field spreads over the adjacent waveguides hence experiencing discrete diffraction. However, at sufficiently high power, the beam self-traps to form a localized state (a soliton) in the center waveguides. Discrete systems have unique properties that are absent in continuous media such as the possibility of producing *anomalous* diffraction.³ As a result, self-focusing and defocusing processes can be achieved in the same medium (structure) and wavelength. This also leads to the possibility of observing discrete dark solitons in self-focusing Kerr media. Recently,⁴ a new discrete diffraction managed nonlinear Schrödinger equation was proposed. This equation admits a novel type of soliton solution whose width and peak amplitude vary periodically.

Here, we propose a new vector discrete diffraction managed soliton system. The vector model describes propagation of two polarization modes interacting in a waveguide array with Kerr nonlinearity in the presence of varying diffraction.⁵ The coupling of the two fields is via the cross-phase modulation coefficient. In the limit of strong diffraction we derive averaged equations governing the slow dynamics of the beam's amplitudes. Stationary (in the form of bright-bright vector bound state) and traveling wave solutions are obtained. Through an extensive series of direct numerical simulations, we study interactions between periodic diffraction-managed solitons for different values of velocities, diffraction and cross-phase modulation coefficient. We find that the interaction picture involves beam shaping, fusion, fission nearly elastic collision and in some cases multi-hump structure.

We begin our analysis by considering an infinite array of weakly coupled optical waveguides with equal separation h . The equations describing the dynamical evolution of coupled beams in a Kerr medium with varying diffraction are given by:⁵

$$i \frac{dU_n}{dz} + \frac{D(z/z_w)}{2h^2} (U_{n+1} + U_{n-1} - 2U_n) + (|U_n|^2 + \eta |V_n|^2) U_n = 0,$$