QWA15 Fig. 1. Absorbance spectra of MIC in (a) DMSO and (b) methanol, and (c) Coumarin in ethanol. The arrows indicate the energy of two photons of the incident pulse.

QWA15 Fig. 2. TBC signal recorded at 790 nm for parallel polarizations. (a) MIC in DMSO and (b) MIC in methanol.

ity dominates, and there is a clear change in the signal when the chirp parameter, C , varies from positive to negative. When the solvent is methanol the TPA peak changes and for the same excitation wavelength the behavior is quite different, as shown in Fig. 2(b). In this case the TBC signal does not seem to vary with changes in the chirp parameter. This is also observed in coumarin, for $\lambda = 800$ nm as shown in Fig. 3(a). The shape of the signal depends on the coherence time of the laser pulses, instead of the pulse duration, as tested by limiting the pulses bandwidth, and changing the chirp parameter. For perpendicular polarizations, Fig 3(b), the signal is one order of magnitude smaller, and its temporal profile suggests a nonlinearity of nuclear origin. A

QWA15 Fig. 3. TBC signal recorded at 800 nm for coumarin with (a) parallel, and (b) perpendicular polarizations.

TPA-mediated thermal process may be responsible for the results obtained in the parallel configuration for MIC in methanol and coumarin in ethanol.

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QWA16

1:00 pm

Spatiotemporal Modulation Instability of Coherent Light in Noninstantaneous Nonlinear Media

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Periodic pattern of optical modulation instability (MI) results from the interplay between the diffraction and self-focusing effects. This interplay amplifies the noise, carried by the light beam, of certain spatial frequency. If the noise is from a static source (e.g. material defects), the resulted MI patterns are no different in either instantaneous or noninstantaneous media. However, it is not the case if the noise is from a dynamic source (e.g. random light scattering). In instantaneous media, MI patterns form instantly depending on the noise distribution. If the material response is noninstantaneous, the always-changing noise cannot alter the index dramatically at any moment, but only to modify the index and consequent MI pattern a bit. Thus, the cumulative MI pattern movement will only be noticeable after a time longer than the material response time. Here, we report on the theoretical derivation and experimental observation of such spatiotemporal MI of coherent light beam in noninstantaneous media. We obtain the MI growth rate as a function of the noise frequency and the material response time. In the experiment, we observe that the varying speed of the MI patterns increases with the decreased material response time. We also observe that increasing the material response time can arrest the MI, agreeing with the theory.

We start from the Helmholtz equation,

$$\nabla_{\perp}^2 A - 2ik \frac{\partial A}{\partial z} + 2k^2 \frac{\delta n(|A|^2)}{n_0} A = 0, \quad (1)$$

with ω the optical frequency, $k = \sqrt{\mu\epsilon_0} \cdot n_0 \omega$ the wave vector, n_0 the unperturbed refractive index, A the amplitude, and δn the optical nonlinearity.

QWA16 Fig. 1. The modulation instability growth rate.

Assuming the nonlinearity is relaxed with time constant τ , the optical nonlinearity

$$\delta n(|E(t)|^2) = \int_{-\infty}^t (1/\tau) F(|E(t_i)|^2) \exp(-(t-t_i)/\tau) dt_i,$$

in which $F(I)$ is the form of the nonlinearity. To study MI, we let A being an unperturbed plane wave plus a perturbation, $A = (A_0 + a) \exp(-i\gamma z)$ with $\gamma = kF(A_0^2)/n_0$, and the perturbation eigenmode as $a = a_1 + ia_2$ with $a_{1,2} = \text{Re} \{ a_{1,2}^0 \exp(i\Omega \cdot t + i\vec{k}_\perp \cdot \vec{r} - i[h_1 + ih_2]z) \}$. Equation (1) is approximated to first order,

$$\nabla_{\perp}^2 (a_1 + ia_2) - 2ik \frac{\partial (a_1 + ia_2)}{\partial z} + \text{Re} \left\{ \frac{4k^2 A_0^2 \kappa a_1^0}{n_0(1 + i\Omega\tau)} \exp(i\Omega \cdot t + i\vec{k}_\perp \cdot \vec{r} - i[h_1 + ih_2]z) \right\} = 0. \quad (2)$$

with $\kappa = [dF(I)/dI]$ being evaluated at $I = A_0^2$. In perturbation, Ω and $\vec{k}_\perp$ represent, respectively, for the temporal and spatial frequencies of the noise, and h_2 stands for the MI growth rate. The condition for Eq. (2) to have nontrivial solution is

$$h_2 = \frac{\kappa}{n_0} k_A^2 \frac{1}{\sqrt{2}} \left(-P^4 + \frac{2P^2}{1+Q^2} + P^2 \left(P^4 + \frac{4-4P^2}{1+Q^2} \right)^{1/2} \right)^{1/2},$$

where $P = k_\perp / (\sqrt{2\kappa/n_0} \cdot k_A)$ and $Q = \Omega\tau$. Figure 1 shows h_2 as a function of P and Q . When $\Omega = 0$ (meaning static noise), Fig. 1(b) shows that h_2 becomes the MI growth rate for instantaneous media, i.e., there is no difference for instantaneous and noninstantaneous media. If the noise is dynamic, the MI patterns can vary in the noninstantaneous media and the patterns should be decided by $\Omega\tau$. Notice that if $\Omega\tau$ is large enough, two changes of h_2 affect the MI the most: (1) h_2 is reduced, causing MI to take longer propagation to develop; and (2) h_2 contains no peak. The reason MI can develop is that the noise of spatial frequency at $k_{\perp, \text{max}}$ with the peak growth rate can win over the noises of other spatial frequencies and makes the refractive index environment more suitable for that particular noise of $k_{\perp, \text{max}}$ to develop into MI. When the growth rate is the same for almost all spatial frequencies, none of them is favored and the MI pattern cannot develop.

In the experiment, an extraordinarily polarized laser light beam (of 572 mW/cm² intensity and $\lambda_0 = 532$ nm) is collimated and launched, along the crystalline a -axis, into a biased photorefractive SBN crystal ($a \times b \times c = 7 \text{ mm} \times 5 \text{ mm} \times$

QWA16 Fig. 2. The movement and deformation of the MI patterns. For example, on the upper-left corner, a stripe (indicated by the arrowheads) disintegrates and its position of highest intensity shifts. Other stripes of the MI pattern shown have similar movements or deformations. This obviously indicates that the noise source is a dynamic one.

QWA16 Fig. 3. (left) MI patterns and optical turbulences formed under different incident optical intensities and applied voltages. (right) The experimentally measured average lifetimes of the MI patterns or optical turbulences. The lifetime is defined as the time at a specific point that the optical intensity goes from a local minimum to a local maximum then back to a local minimum.

5 mm, $r_{33} = 280$ pm/V and $n_0 = 2.35$), that acts as the noninstantaneous self-focusing medium. When we apply a voltage of 0.75 kV on the crystal with polarity against the c -axis, we observe that the patterns continuously move [e.g., Fig. 2] for more than a few hours (much longer than the material response time) and never stop, indicating that the noise is dynamic.

The theory predicts that increasing material response time can arrest MI. Therefore, the MI pattern can be eliminated if the response time is long enough, that can be done by reducing the optical intensity for photorefractive materials. We set the voltage at 0.9 kV and tune the optical intensity. Figure 3(a) shows that, at 57.2 mW/cm², the MI cannot develop, and when the intensity is above 286 mW/cm², the MI pattern is clearly seen. The trend that the varying speed of the MI patterns increase with the decreased response time (roughly inversely proportional to the optical intensity in photorefractive material²) can be characterized by the lifetime shown in Fig. 3 as we fix the voltage at 0.9 kV (1.1 kV, or 1.5 kV) and change the optical intensity to different values. Even to our surprise, the MI patterns may break up into randomly moving and distributed speckles when the optical intensity is above some voltage-dependent threshold (e.g., at 1.1 kV the threshold intensity is about 572 mW/cm²). We call these random speckles as optical turbulence and conjecture that it may be related to the turbulence of the viscous flows.

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QWA17

1:00 pm

Guide Properties in an Array of Spatial Solitons: Experimental and Numerical Studies

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1. Introduction

Since the first prediction of spatial soliton in photorefractive materials, and the first experimental observation of self-focusing ability and soliton formation in a photorefractive crystal,¹⁻² the spatial solitons in this kind of materials was an area of great interest. The generation of an array of dark solitons stripes in the spatial domain is now a field of research. Array of dark spatial solitons has been observed in self-defocusing materials when a gain is introduced.³⁻⁵

Theoretically we can have a transverse field distribution evolves into a periodic array of clean and stable dark solitons stripes, the waveguide

properties of these arrays of solitons, to implement a new type of devices, are in process of study and have not been demonstrated totally.

2. Numerical results

To understand the effect of the array on the probe beam it is necessary to see what is the behaviour of the probe beam when there is one dark spatial soliton only. A fundamental dark soliton, see fig 1, induces a waveguide for another beam where photorefractive effect is negligible. We observe what happens to this beam when is launched at different angles, widths and positions, with respect to the fundamental soliton

For angles smaller to 0.8 rad, the soliton acts like a waveguide, the amplitude of the probe beam never decrease more than 50%. For angles higher to 0.8 rad does not exist efficient guiding. We can observe too that the best guiding was obtained when the beam was positioned as far as two times its width.

In the fig. 2, we plot the numerical simulation when was produced another fringe and the probe beam was in the center of one dark fringe. In these case all the energy was moved to the more closed dark soliton generated.

The numerical simulation showed that is possible to generate an array of dark spatial solitons inside of photorefractive media with a drift mechanism of nonlinearity.

3. Experimental results

Now is possible understand well what could happen if we have an array of spatial solitons. The array can be generated experimentally when two plane waves interference in the nonlinear media. Depending on the period of this pattern and the voltage, we observe the formation of an array of

QWA17 Fig. 1. Dark spatial fundamental soliton, and a probe beam for an angle of 0.6 rad and to different widths.

QWA17 Fig. 2. One strip more in the array with probe beam.