High-Order Modulation Instability

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Outline

- Background & Motivation
- Experimental Configurations
- 1-D Spot Arrays: Experiment and Simulation
- 2-D Cones: Experiment
- Conclusions & Future Work

Background

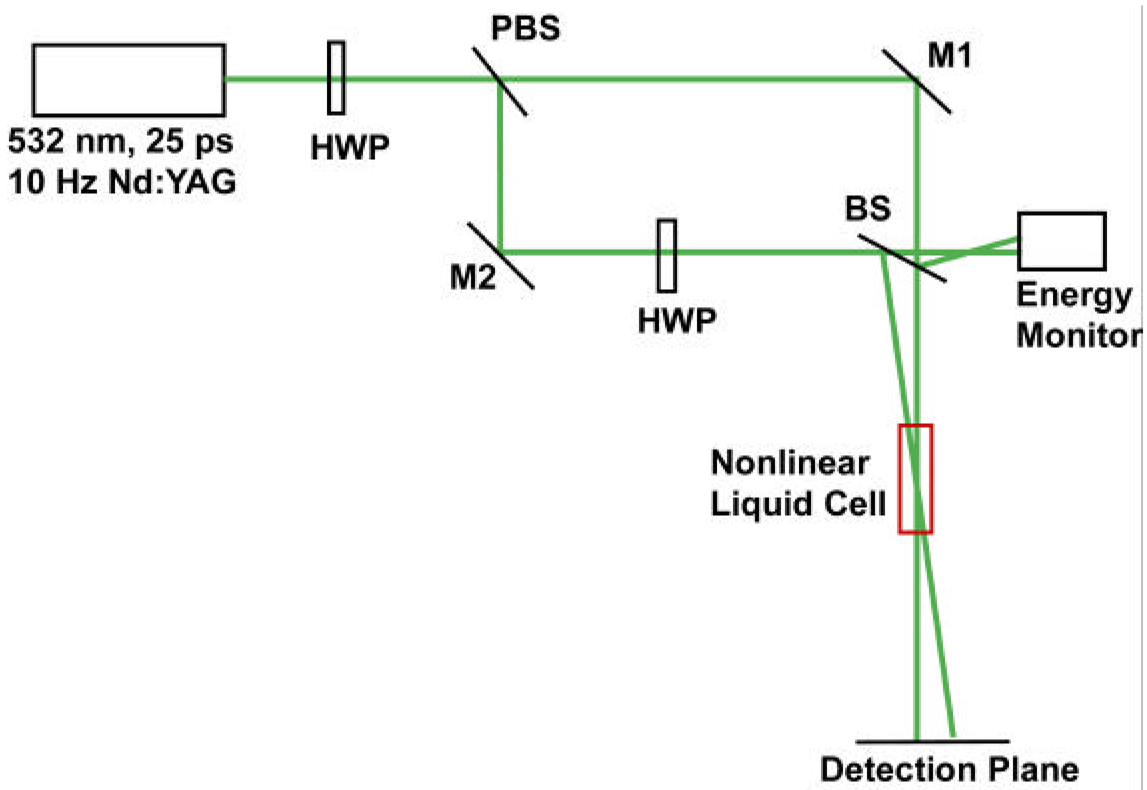
- Experimental & theoretical studies of pattern generation from two intersecting beams:
  - Kauranen et al., JOSA B 10, 2298 (1993)
    Theoretical treatment
  - Chalupczak et al., Opt. Comm. 111, 613 (1994)
    Experimental treatment in barium vapor
  - Many, many more!

- Use of two intersecting beams to reduce filamentation
  - Maillotte et al., Opt. Comm. 109, 265 (1994)

Motivation

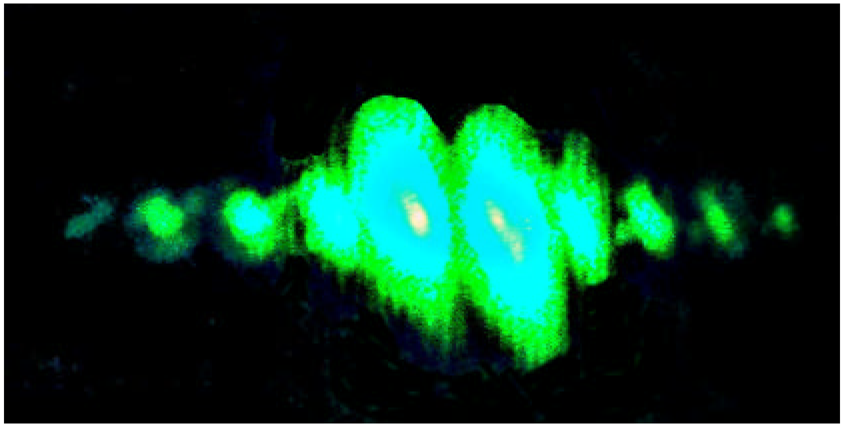
- Reduction of laser beam filamentation
- Generation of quantum states of light
- Fundamental interest in nonlinear optical pattern formation

Experimental Configurations



- Used 3-cm and 10-cm cells
- Used CS_2, CCl_4, and toluene
- Pulse intensities ~ 1-80 MW/cm^2
- Crossing angles ~ 0.003-0.04 rad

1-D Spot Arrays: Experimental Results



- At small angles (~ 0.003 rad), a 1-D array of spots is observed

- Many orders of self-diffraction were visible (12+ ; 8 pictured)

- Properties of the spots (number, intensity, etc) critically dependent on properties of input beams

- Clearly observable thresholds

1-D Spot Arrays: Numerical Simulations

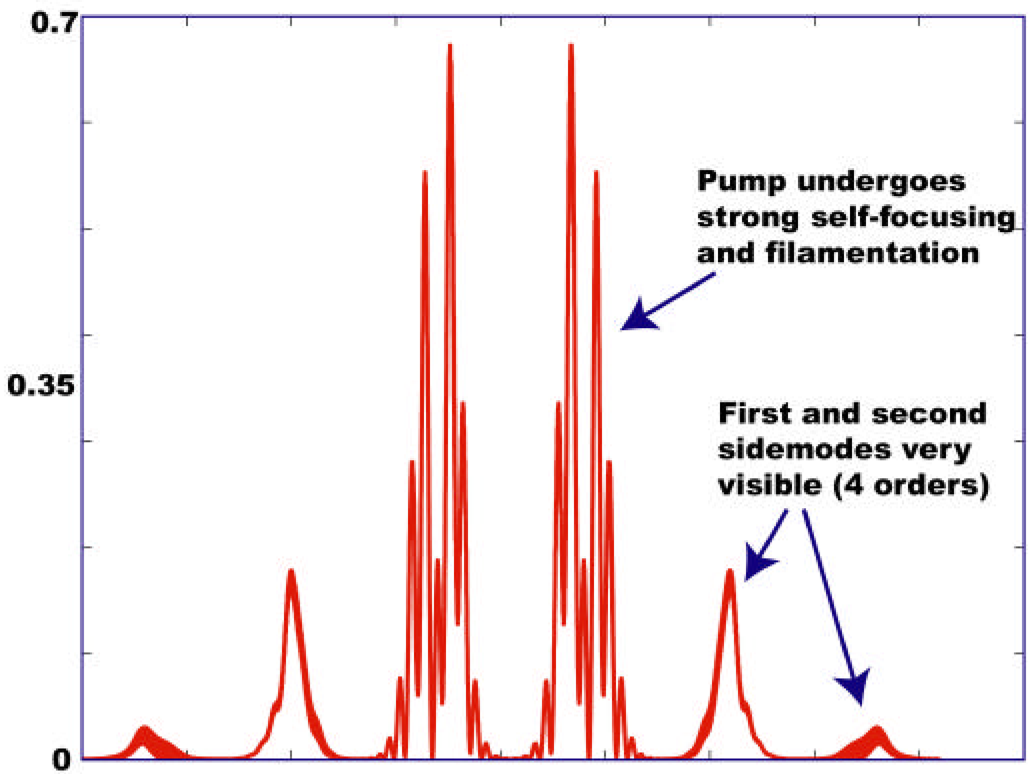
- **Modeled experiment using split-step Fourier method to solve NLSE numerically**

$$\frac{\partial A}{\partial z} = \frac{i}{2k_o} \nabla_\perp^2 A + ig \left| A \right|^2 A \qquad \textbf{where} \qquad g \equiv \frac{n_o n_2 w_o}{2p}$$

- **Results for 1-D case in close agreement with experiment**

- **Using simulation to predict interesting aspects for further experimental studies**

1-D Spot Arrays: Numerical Simulations



- Transverse intensity profile output:

10-cm CS_2 cell
q = 3.2 x 10^{-3} rad
I = 11.3 MW/cm^2 (each)
w_o = 2.32 mm

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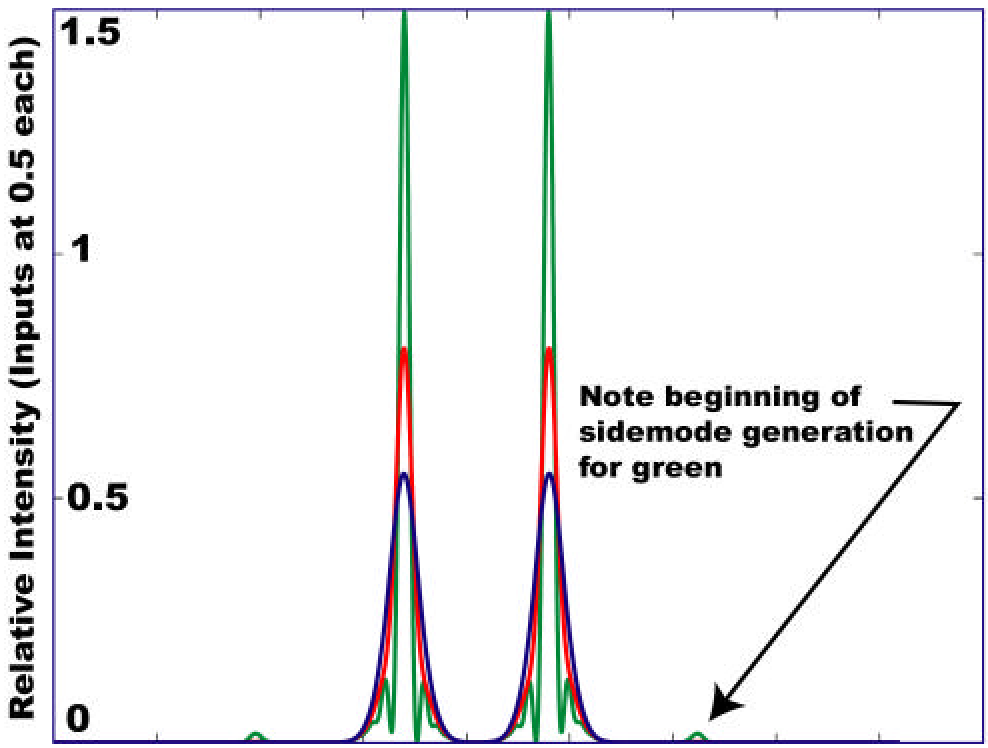
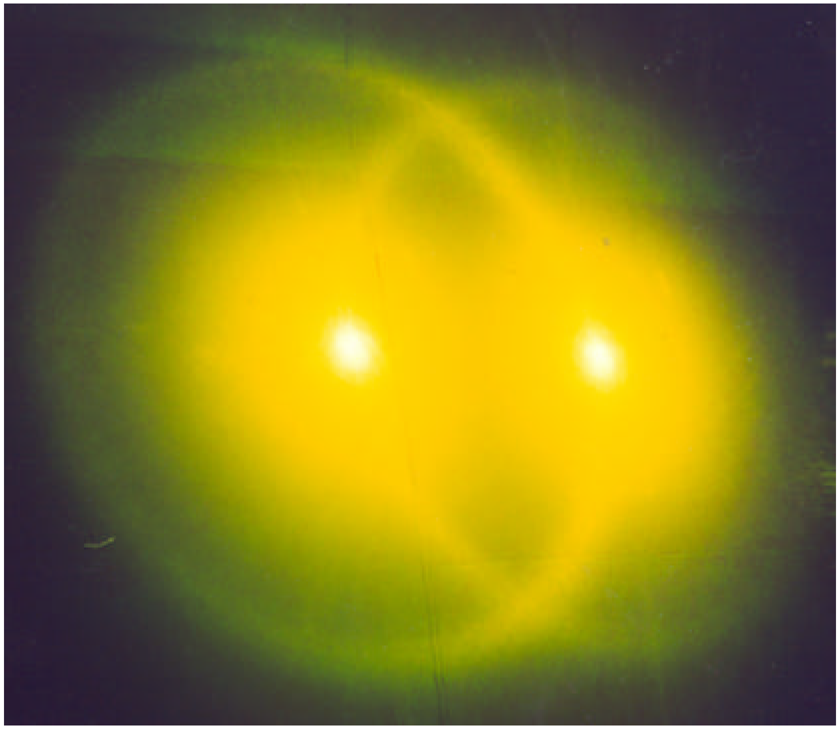
1-D Spot Arrays: Numerical Simulations



- Blue: 2.8 MW/cm^2
- Red: 5.7 MW/cm^2
- Green: 8.5 MW/cm^2
- As intensity increases, first see self-focusing, then filamentation and spot generation.

2-D Cones: Experimental Results



- At “large” angles (~ 0.03 rad), cones of light are observed

- The cones are centered about one beam and pass through the other

- Properties of the cones are primarily dependent upon beam which they intersect

- Clearly observable thresholds

2-D Cones: Experimental Results

- **Threshold measured for multiple materials, cell lengths, and spots sizes and remained constant in nonlinear phase:**

$$f_{NL} = n_2 I l k_o$$

$$f_{NL}^{th} \sim 0.19 rad \qquad f_{NL}^{pics} \sim 0.75 rad$$

- **Threshold independent of angle over large range**
- **Cones persisted down to ~ 15 mrad pump seperation**

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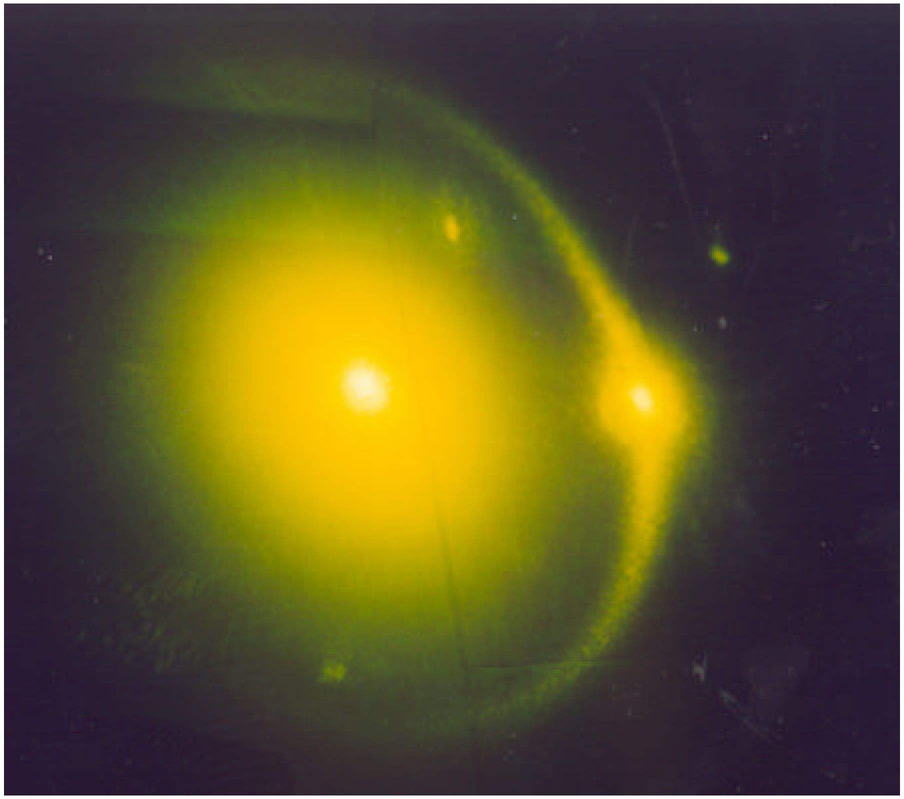
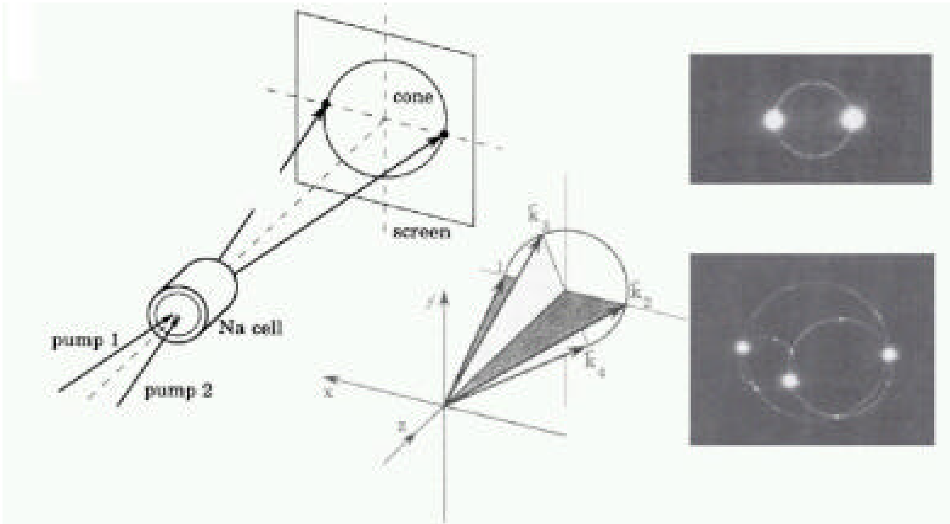
2-D Cones: Experimental Results



- Case where one beam (right) highly attenuated
- Note that left beam acts as pump and right beam acts as seed for the generated cone
- Polarization follows seed, not pump

Other Experimental Regimes

- In the intermediate angular range (~ 5-15 mrad for this case), two-beam conical emission has been seen in vapors:



Kauranen et al, Opt. Lett. 16, 943, 1991; Kauranen and Boyd, Phys. Rev. A, 47, 4297, 1993.

- Should TBCE be expected in nonlinear liquids as well?

Other Experimental Regimes

- **What about larger (> 40 mrad) and smaller (< 3 mrad)?**
  - **Larger angles will reduce interaction length, where self-action effects would likely dominate**
  - **Smaller angles add experimental difficulties, but may or may not show interesting features**

- **Unbalanced pumping effects?**
  - **Preliminary simulations show interesting results**

- **Pump polarization effects also being explored**

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Conclusions & Future Work

- Generated variety of patterns from two-beam interactions in nonlinear liquids
- Patterns strongly dependent on experimental parameters
- Can accurately model 1-D patterns numerical--need to extend modeling to 2-D case
- Explore quantum correlations in patterns

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