Coherent Control of Four-Wave Mixing Gain

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Outline

• Filamentation Basics

• Filamentation Reduction--Theory and Experiment

• Two-Beam Experiment: Self-Diffraction

• Two-Beam Experiment: Conical Emission

• Future Work and Conclusions
Filamentation Basics

For a material with a real, positive nonlinearity, there is a given power ($P_{cr}$) above which propagation leads to significant changes in the beam.

Self-Focusing, $P > P_{cr}$

Self-Trapping, $P = P_{cr}$

Filamentation, $P >> P_{cr}$
Filamentation Basics

Filaments Grow From Perturbations (classical or quantum) on the Wavefront Via a Near-Forward Four-Wave Mixing Process:

\[ k_1 = k_0 + q \quad \text{and} \quad k_2 = k_0 - q \]

Energy is Depleted From the Main Beam and Added to the Side Modes, With Gain Dependent on \( q \):

\[
A_1(z) = (A_1^+ e^{g_+z} + A_1^- e^{g_-z}) e^{i\Delta k z / 2}
\]

\[
g = q \left( n_2 E^2 / n - q^2 / 4k^2 \right)^{0.5}
\]
Filamentation Reduction Theory

Let $A_1$ and $A_2$ be the side-mode amplitudes:

$$A_1(z) = \frac{1}{2} \left[ A_1(0) + \frac{\kappa}{g} A_2^*(0) \right] e^{g z} + \frac{1}{2} \left[ A_1(0) - \frac{\kappa}{g} A_2^*(0) \right] e^{-g z}$$

$$A_2^*(z) = \frac{1}{2} \left[ A_2^*(0) + \frac{g}{\kappa} A_1(0) \right] e^{g z} + \frac{1}{2} \left[ A_2^*(0) - \frac{g}{\kappa} A_1(0) \right] e^{-g z}$$

where: $\kappa = \frac{6 \pi \omega}{n c} \chi^{(3)} A_0^2$ and $\frac{\kappa}{g} = i$.

If set the relative side-mode phases such that:

$$\frac{A_2^*(0)}{A_1(0)} = i$$

then side-modes will experience no gain.

Filamentation Reduction Experiment

Laser: 25 ps, 532 nm, < 25 mJ
Filamentation Reduction Data

![Experimental Data Graph]

- Filamentation Reduction Data
- Experimental Data
- Side-Mode Phase Difference (degrees)
- Generated Side-Mode Energy (microjoules)
Two-Beam Experiments

- Use of two intersecting beams to reduce filamentation

- Experimental & theoretical studies of pattern generation from two intersecting beams:
  - Kauranen et al., JOSA B 10, 2298 (1993)
    Theoretical treatment
    Experimental treatment in barium vapor
Two-Beam Coupling Experiments

- 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

532 nm, 25 ps
10 Hz Nd:YAG
Two-Beam Coupling: Self-Diffraction

- Transverse intensity profile output:

10-cm CS₂ cell
θ = 3.2 \times 10^{-3} \text{ rad}
I = 11.3 \text{ MW/cm}^2 \text{ (each)}
\omega_0 = 2.32 \text{ mm}
Two-Beam Coupling: Conical Emission

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

- Two types: cones centered about one beam and pass through the other, and cones connecting two beams (TBECE)

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

- Clearly observable thresholds
Two-Beam Coupling: Conical Emission

Possible Future Work

• Optimize filamentation reduction experiment

• Explore other methods of filamentation reduction

• Investigate quantum-induced filamentation

• Search for correlations in two-beam generated patterns
Conclusions

• Demonstrated a method for filamentation reduction

• Studied related two-beam interactions in nonlinear liquids

• Witnessed self-diffraction, two-beam excited conical emission, and seeded spatial modulation instability

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