2010 NASA Innovation Fund: Optical Phased Array Transmitter

Problem: Optical communications requires precise pointing

Current Solution:

- High peak power pulsed laser
- Pulse position modulation
- Mirror for point ahead
- Intensity-only photon counters

Future Innovation:

- High efficiency CW laser
- Phase modulation
- Phased array beam steering for point ahead
- Quantum-limited phase-sensitive detectors

Key New Insight:

- Semiconductor diode lasers can be used to build optical phased lock loops (OPLL's) with *fully electronic* servo control.
- Many OPLL's can be arrayed for a scalable phased array solution.

Accomplishments:

- Theoretical analysis
- Experimental demonstration of 2 laser proof-of-principle
- Identification of key technology challenges

Start/End TRL: TRL1/TRL2

Key Challenges:

- Fill-Factor
- Number of array elements

Next Steps:

- 1-D steering demonstration
- On-chip integration to overcome challenges

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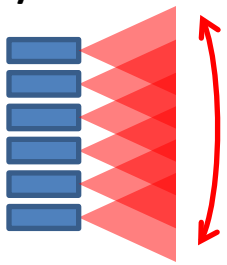

Enables new paradigm:
3X power efficiency, ½ mass transmitter assembly!

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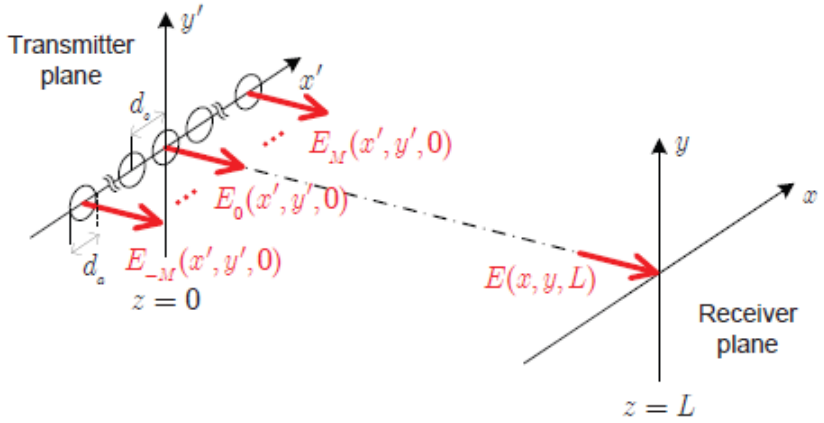
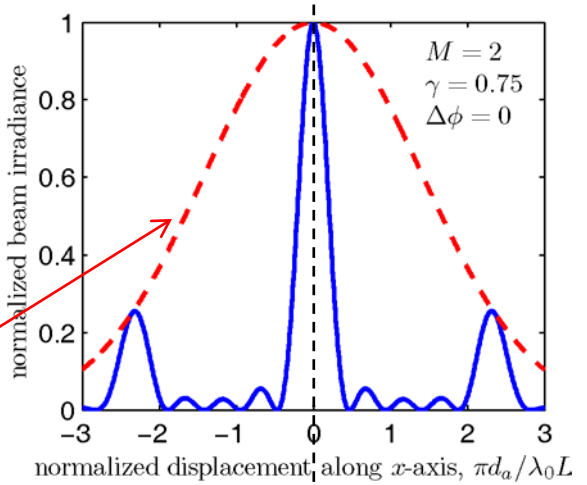
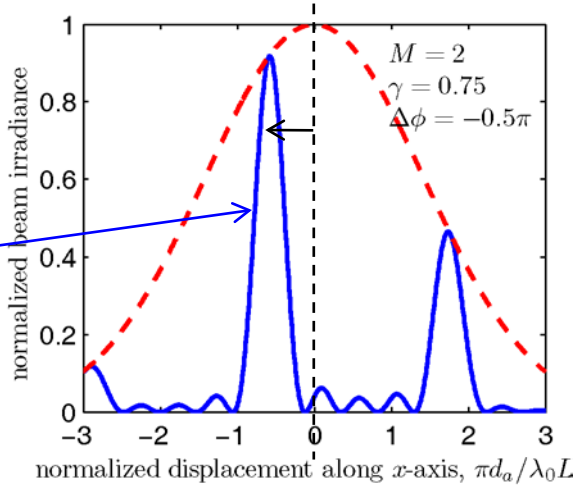
Theoretical Analysis







- $2M+1$ laser emitters at transmitter
- Paraxial free-space propagation
- Linear phase relationship, with $\Delta\phi$ increments
- Far field intensity profile given by

$$I(x,y,L) \equiv |E(x,y,L)|^2 = \frac{P_0 d_a^4}{\lambda_0^2 L^2 A}\left|\mathcal{W}\left(\frac{2\pi d_a}{\lambda_0 L}x, \frac{2\pi d_a}{\lambda_0 L}y\right)\right|^2 \left|\mathcal{E}\left(\frac{2\pi d_s}{\lambda_0 L}x - \Delta\phi\right)\right|^2$$

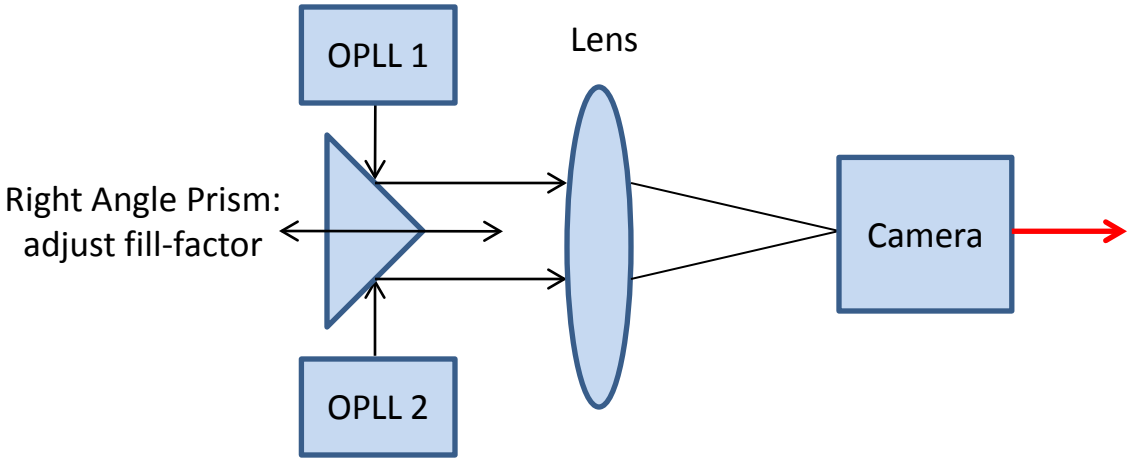
Steering envelope: beam profile of individual emitters

Steered beam: interference pattern from all emitters

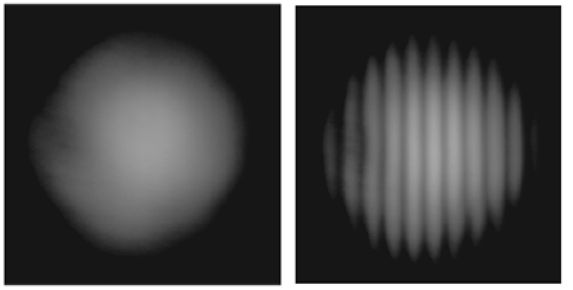
- Key enabling parameters for optical communication are fill factor > 0.75 and number of emitters > 1000

Experimental Demonstration

Experimental setup to measure the intensity profile in the far-field.

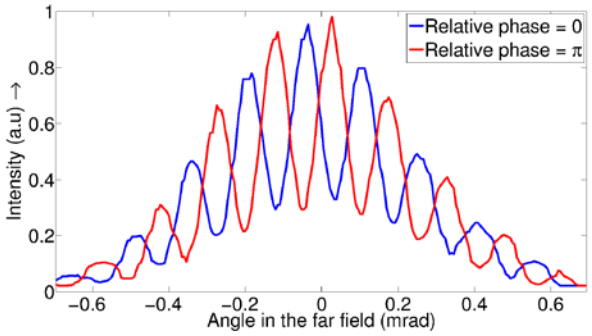


Far Field Interference Pattern

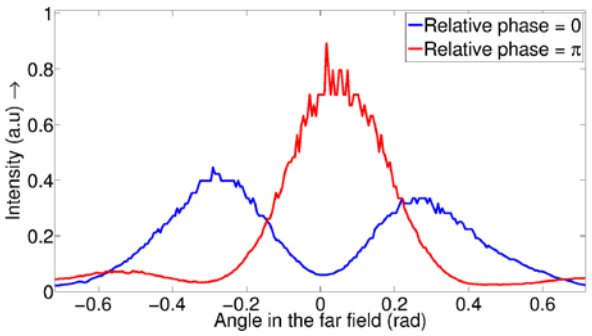


Unlocked Phase-locked

Dependence of Sidelobes on Fill-Factor



Low Fill-factor



High Fill-factor