

The Status of Melody: An Interferometer Simulation Program

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- Melody overview
 - » Program functionality
 - » New features
- Predicting interferometer behavior under thermal load with Melody
 - » Predictions of Power Recycling Cavity Sideband Gain
 - » Symmetric/Asymmetric Interferometer losses
 - » Mode Shapes
- Ref: Beausoleil et al., Model of Thermal Wave-Front Distortion in Interferometric Gravitational Wave Detectors I: Thermal Focusing, JOSA B, June 2003

- Simulate thermally loaded interferometer in Matlab
 - » Any passive interferometer configuration
 - » Gain (ex. recycling cavity gain)
 - » Thermal lensing, deformation curvature
 - » Field profiles
- Variable parameters:
 - » Input power
 - » Modulation frequency, depth
 - » Number of modes
 - » Test mass parameters: substrate/coating absorption and scattering, curvature, etc.
 - » Tilt angle

Modal Expansion for Self-Consistent Fields

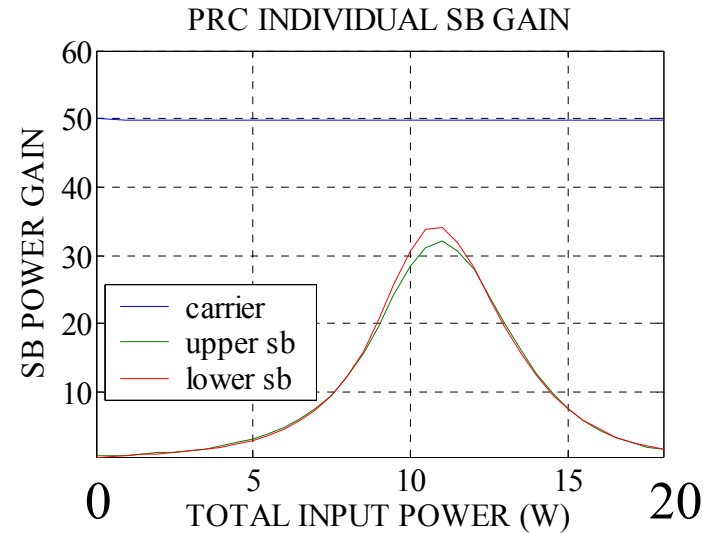
- IFO fields represented as a finite set of Hermite-Gauss Modes
 - » X-arm serves as a reference for the basis
- IFO described in matrix form
 - » Operators (matrices) for aperture diffraction, wavefront curvature mismatch, thermal focusing, thermoelastic surface deformation, tilt
- Self-consistent fields
 1. Compute absorbed power in substrate and coatings, update thermal operators
 2. Maximize recycled power
 - a. Independently move ITMs for maximum carrier power
 - b. Adjust beamsplitter for dark port condition
 - c. Adjust recycling mirror for maximum recycled carrier power
 3. Recompute the intracavity fields and repeat steps 1 and 2 until the recycled power has stabilized to the desired accuracy

- Scripts with relevant interferometer parameters
 - » Test mass curvature and substrate absorption from G. Billingsley's website
 - » Relevant mode cleaner configurations also included
- Pre-computed file creation more user friendly
- Field surface plots and beam cross-sections
 - » Carrier, sidebands plotted directly
 - » Phase camera emulator (next release)
- Test mass tilt
- Gravitational wave response

- Melody simulates an optimized IFO
- Too little thermal loading predicted for LHO 2k, LLO 4k
- Too much thermal loading causes early SB rollover in LHO 4k
 - » Peak gain at 2.5 W input power
 - » Melody predicts peak gain at 11 W input power
- Possible causes:
 - » Optic curvature
 - » Asymmetric Losses in each arm

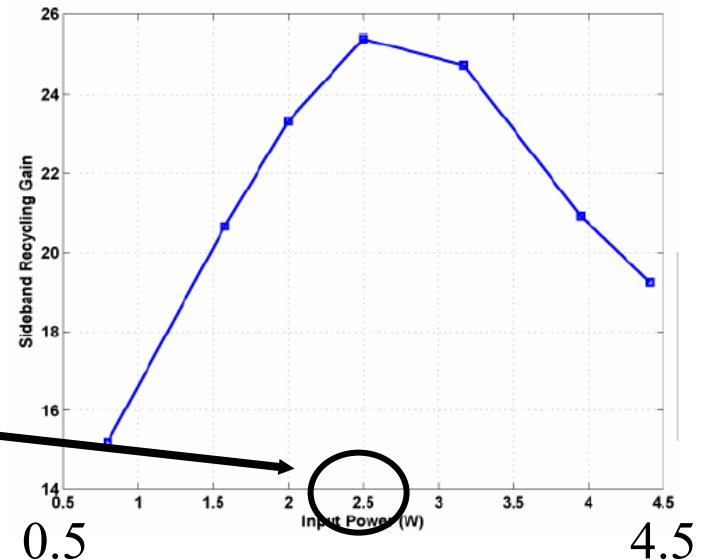
Data from Melody
Using LHO 4k
Parameters

Peak Gain ~ 35



Data from LHO 4k
Peak Gain ~ 25
Expected Gain ~ 35

2.5W SB Rollover



Courtesy A. Gretarsson

Symmetric, Low Loss

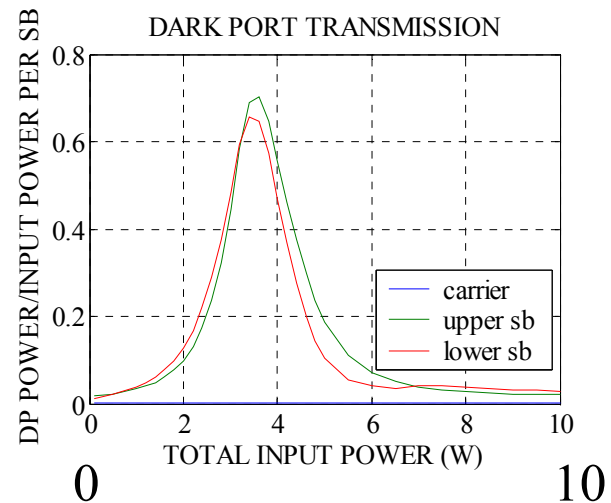
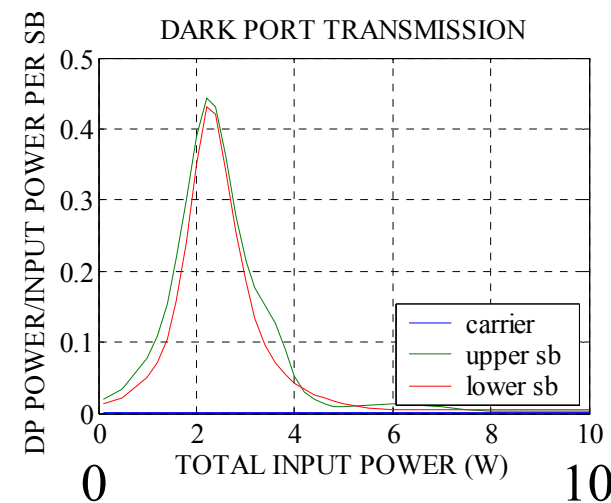
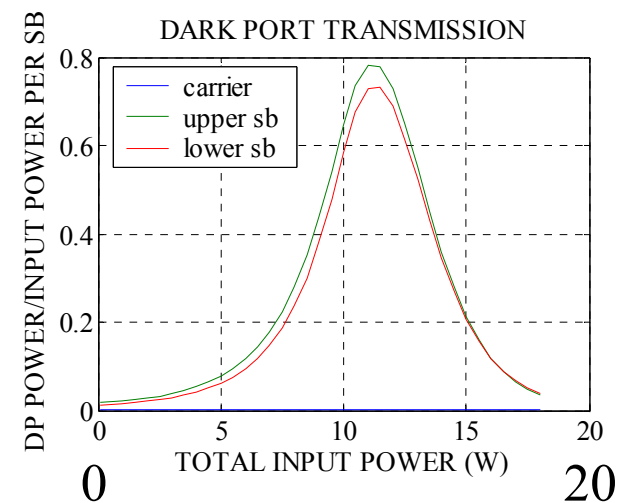
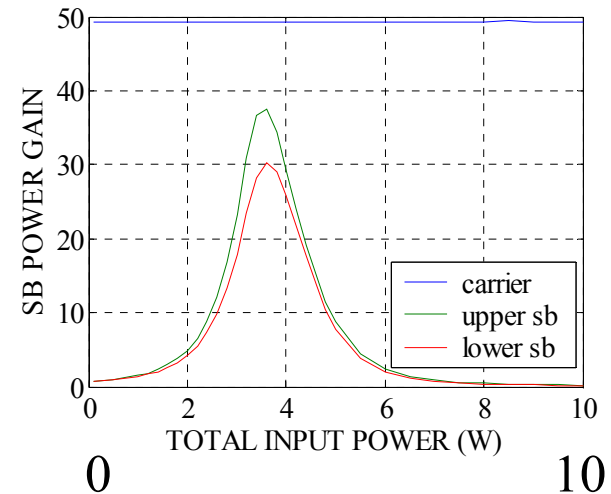
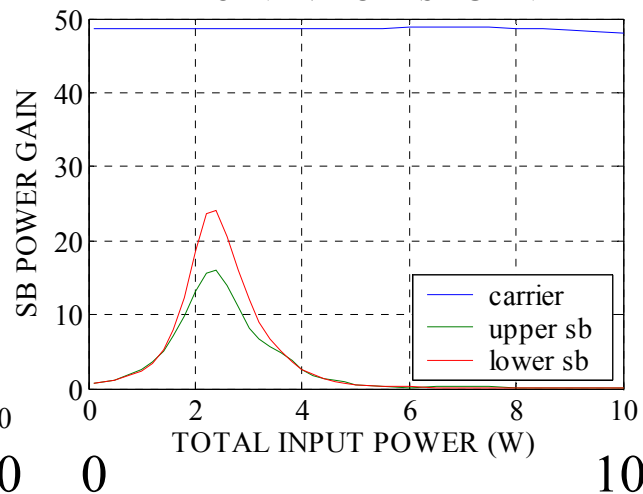
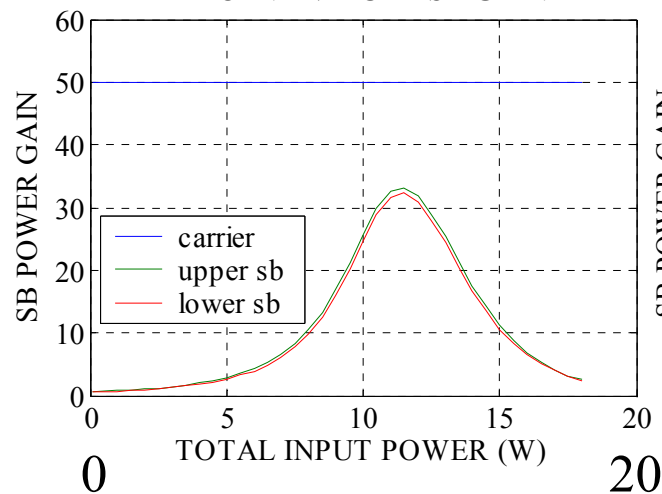
Asymmetric, ITMx AR High Loss

Symmetric, ITM High Loss

PRC INDIVIDUAL SB GAIN

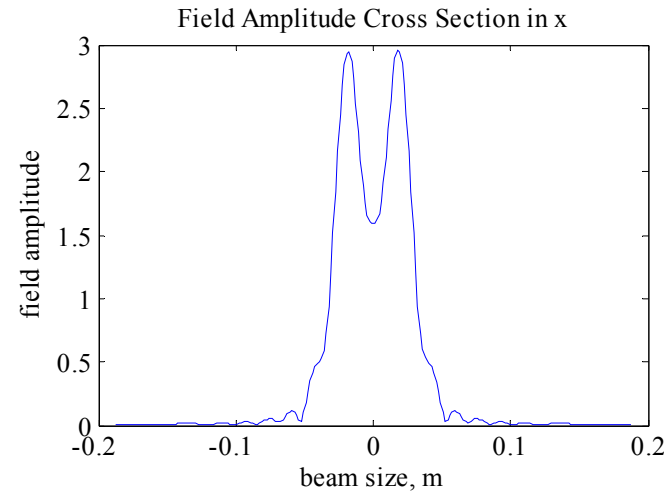
PRC INDIVIDUAL SB GAIN

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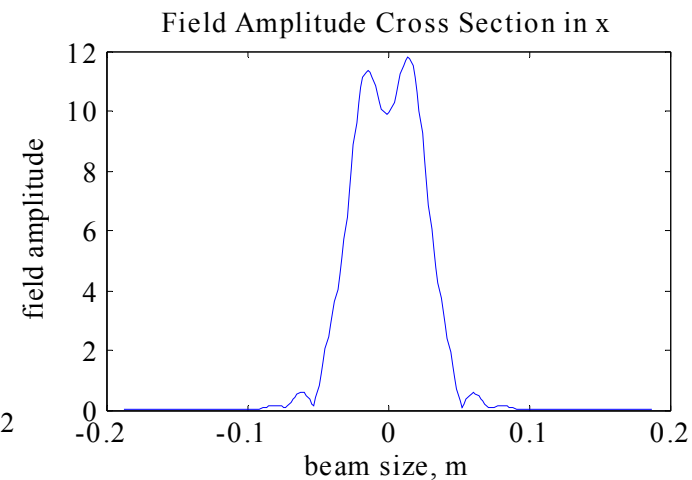
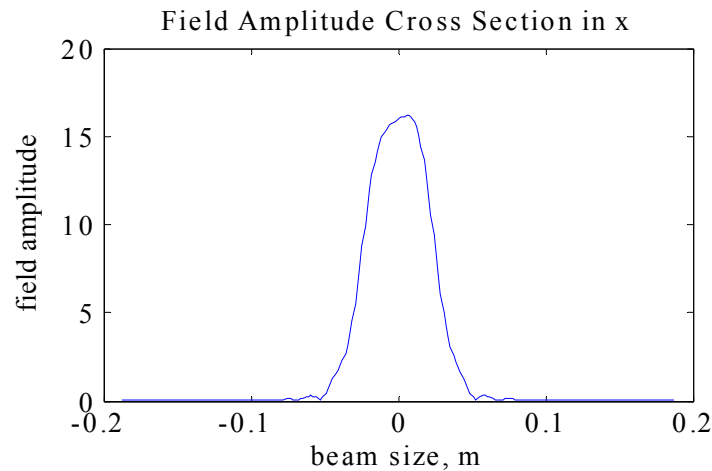
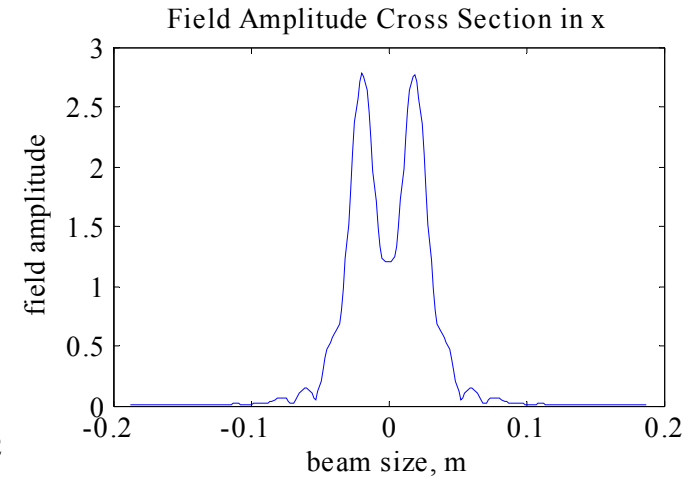


- LHO 4k parameters
- 136 HG modes
- 1W total input power
- Sidebands show interesting structure
- 8W total input power
- Sidebands have more TEM_{00} content, especially the upper SB

Upper SB

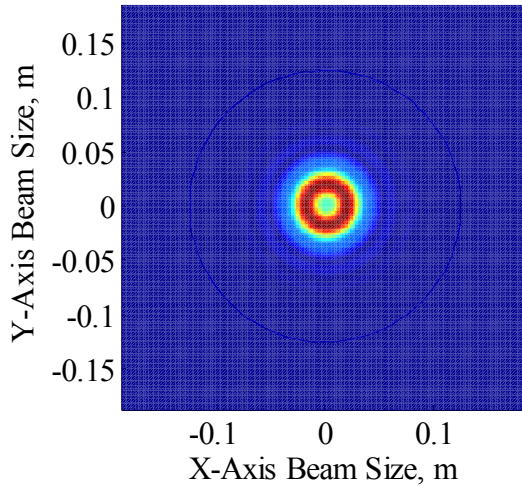


Lower SB

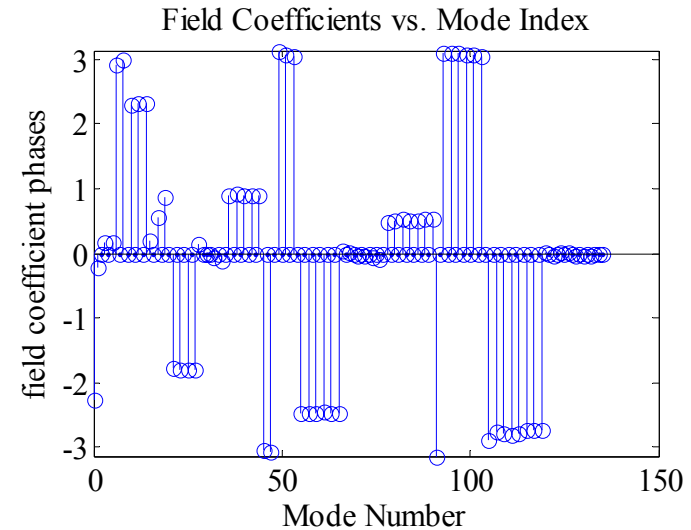
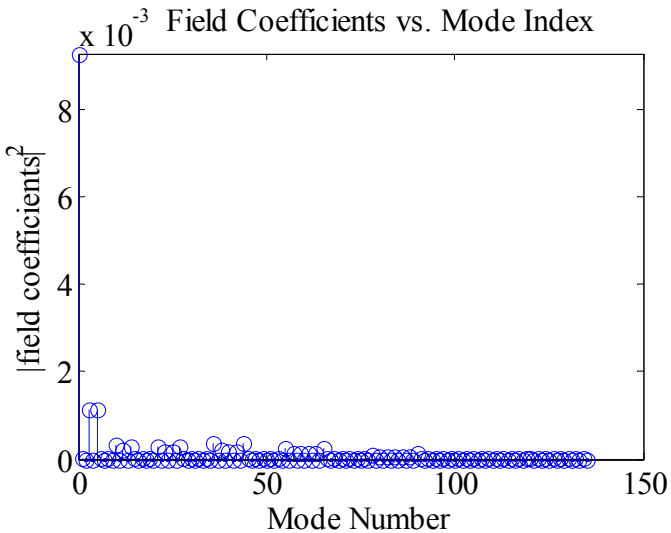
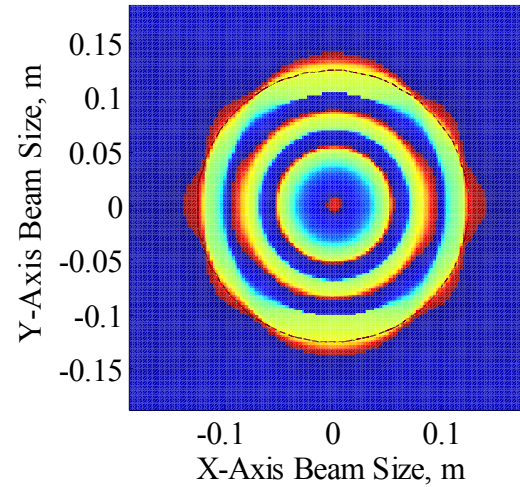


LHO 4k Lower Sideband, 1W Input Power

Field Amplitude Map



Field Phase Map



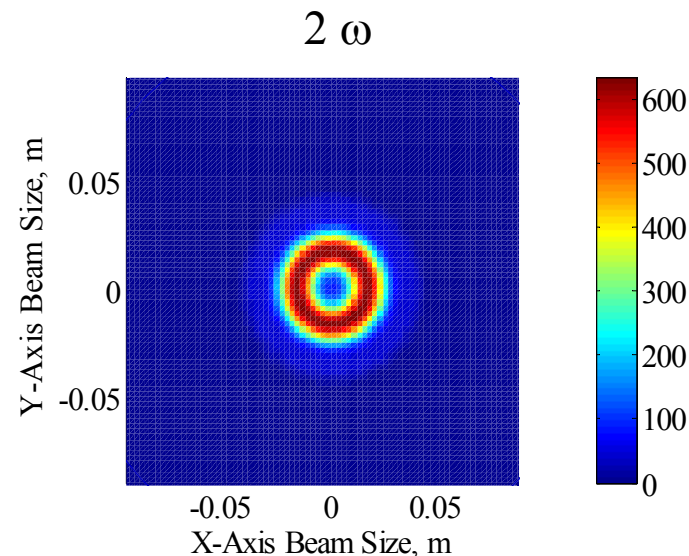
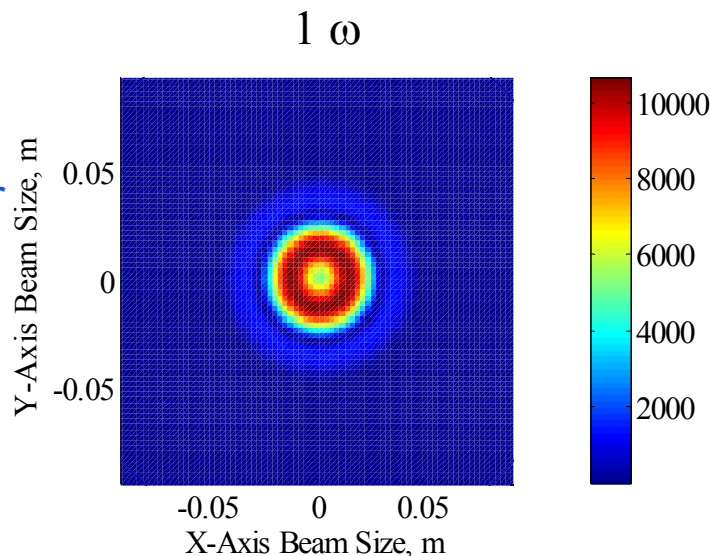
- Melody Phase Camera Emulator

- » Demodulation at 1ω and 2ω
- » 153 modes

- Power recycling intracavity fields

- LHO 4k phase camera

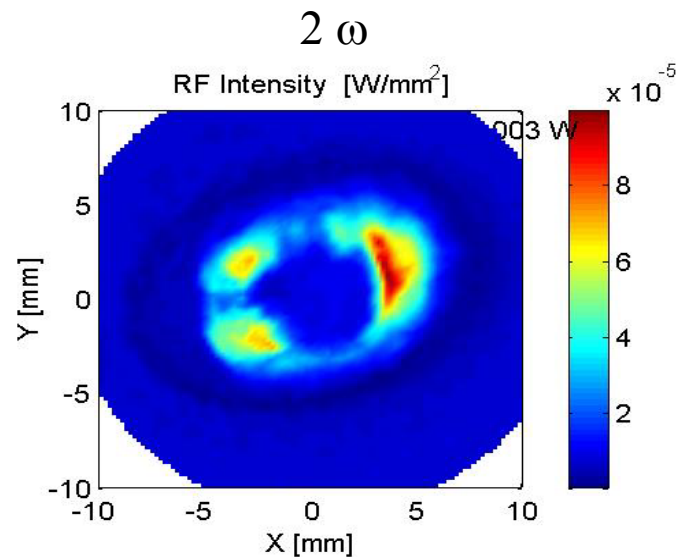
- » Demodulation at 1ω and 2ω
- » Courtesy J. Betzweiser

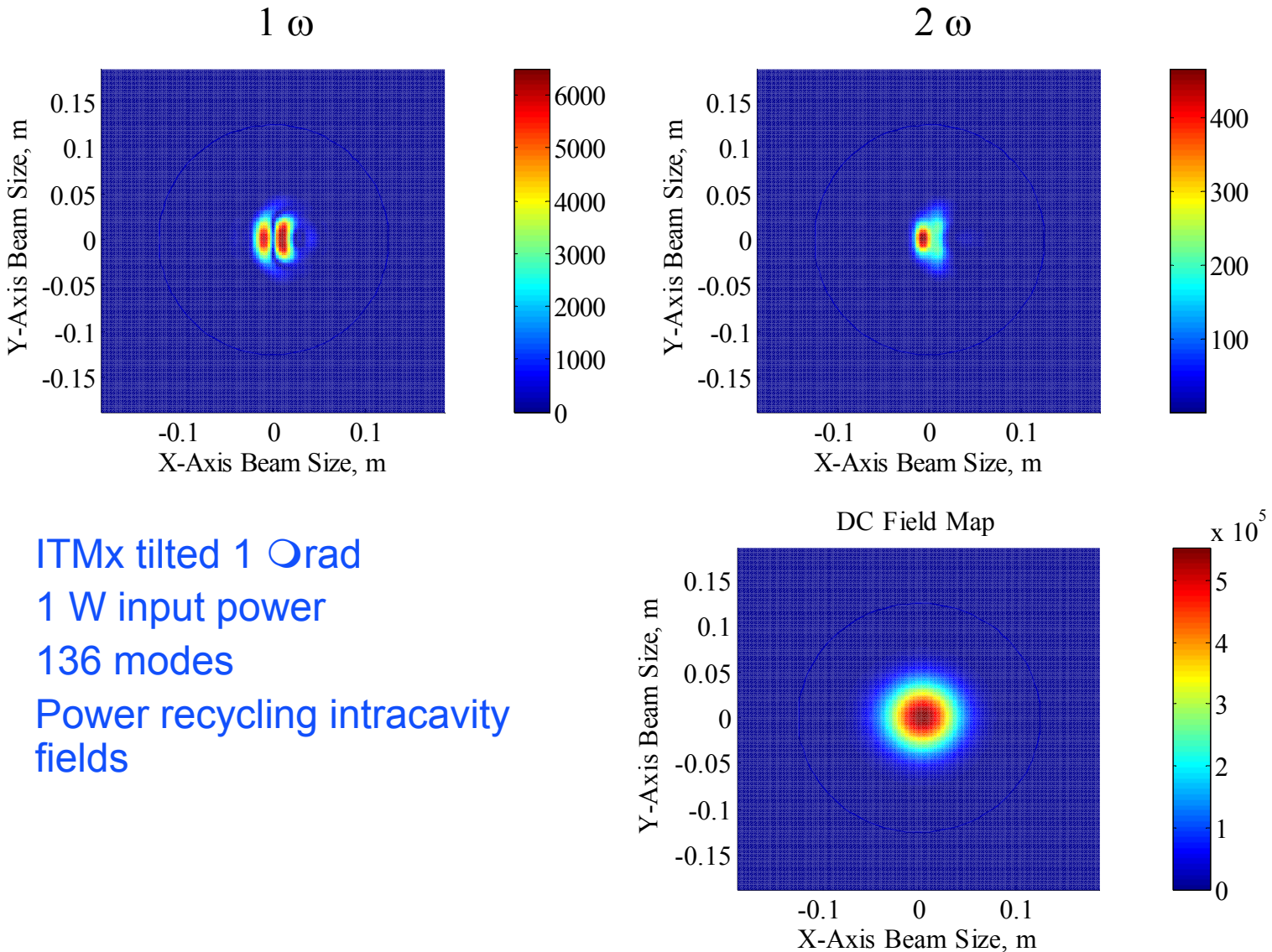


$$Picture = \sqrt{|I|^2 + |Q|^2}$$

$$I = In - phase$$

$$Q = Quadrature$$





- Melody uses Hermite-Gauss modes to represent IFO fields
- New features can be used to compare IFO behavior to simulations
- Recycling cavity gain, mode shapes, thermal lensing, response to asymmetric loss, etc. can be simulated
- Next release ...
 - » Phase camera emulator
 - » Cross section plots
 - » Astigmatism
 - » Thermal Compensation
- And beyond ...
 - » Thermal loading with inhomogeneous absorption