Diagnostic Breadboard

A compact, automated diagnostic instrument for laser beams

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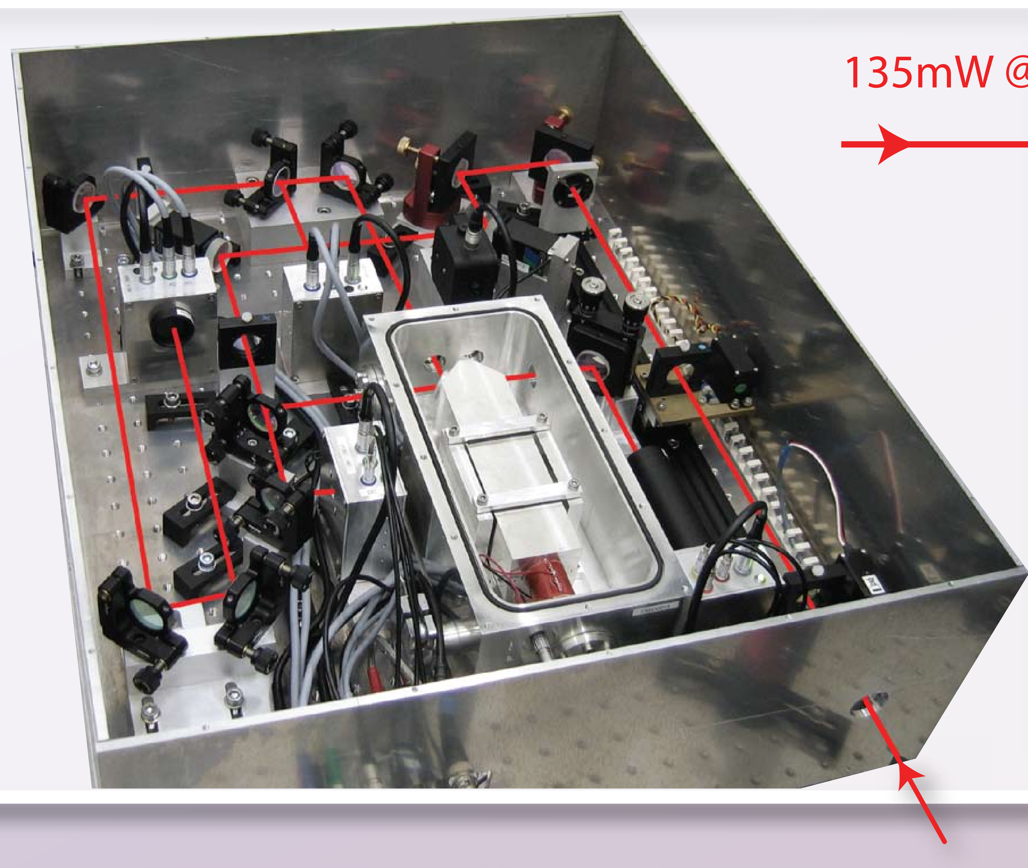
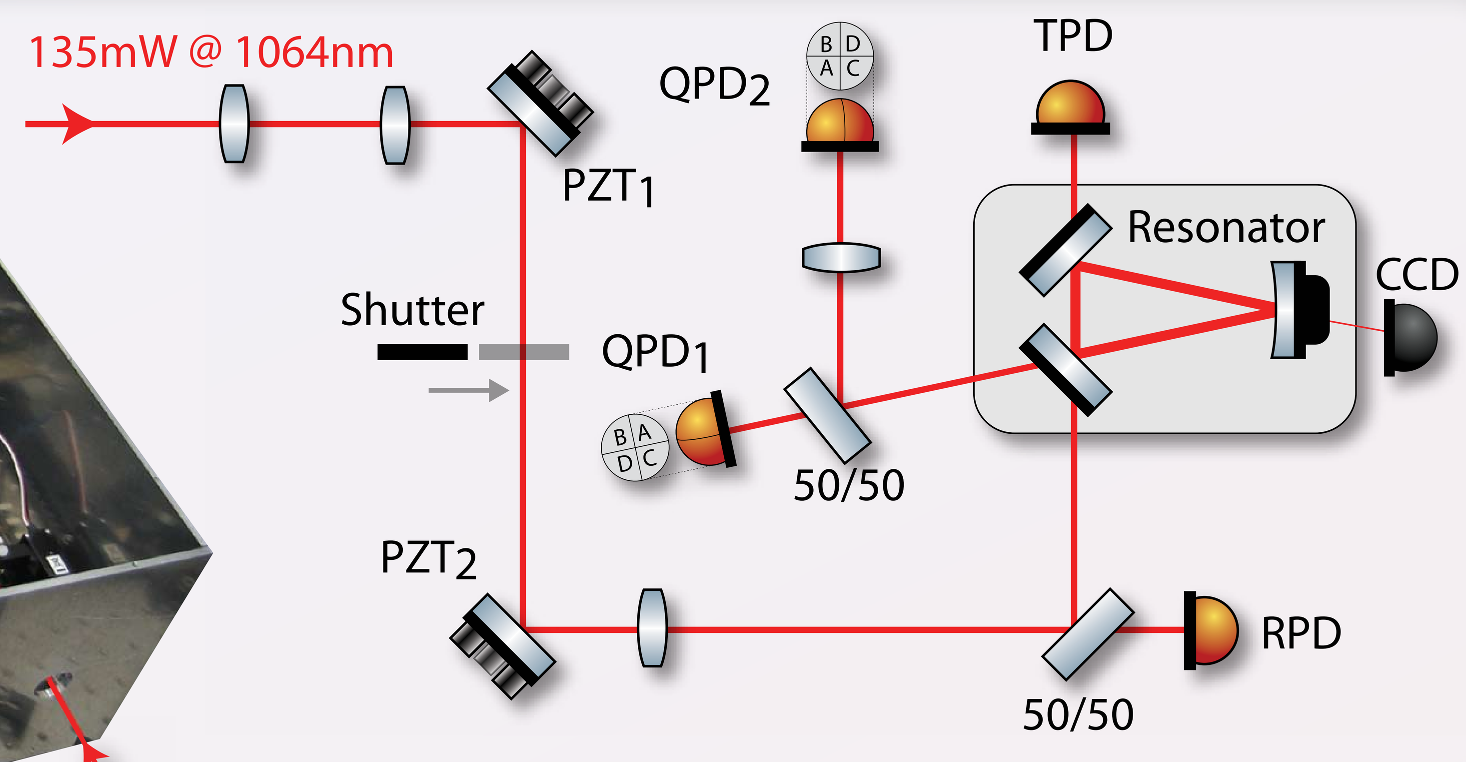
Introduction

- Characterization of linearly polarized, single-frequency, continuous wave laser beams at 1064nm wavelength:
  - Power noise, 1 Hz to 100 kHz and 1 MHz to 100 MHz
  - Frequency noise, 1 Hz to 100 kHz
  - Beam pointing fluctuations, 1 Hz to 100 kHz
  - Spatial beam quality
- Characterization is completely automated
- Compact (61cm x 50cm) laser beam diagnostic instrument
- Characterized several different laser systems:
  - Eight 2W Nd:YAG nonplanar ring oscillators (NPROs) [5]
  - 35W Nd:YVO4 amplifier system [4]
  - Yb-doped photonic crystal fiber amplifier [3].





Beam Quality

- Measured with mode scan technique
- Beam is expanded into eigenmodes of the ring resonator:
  - Resonator is scanned with piezoelectric element and transmitted power is measured with TPD
  - Total power in higher-order TEM modes is determined

Sensitivity

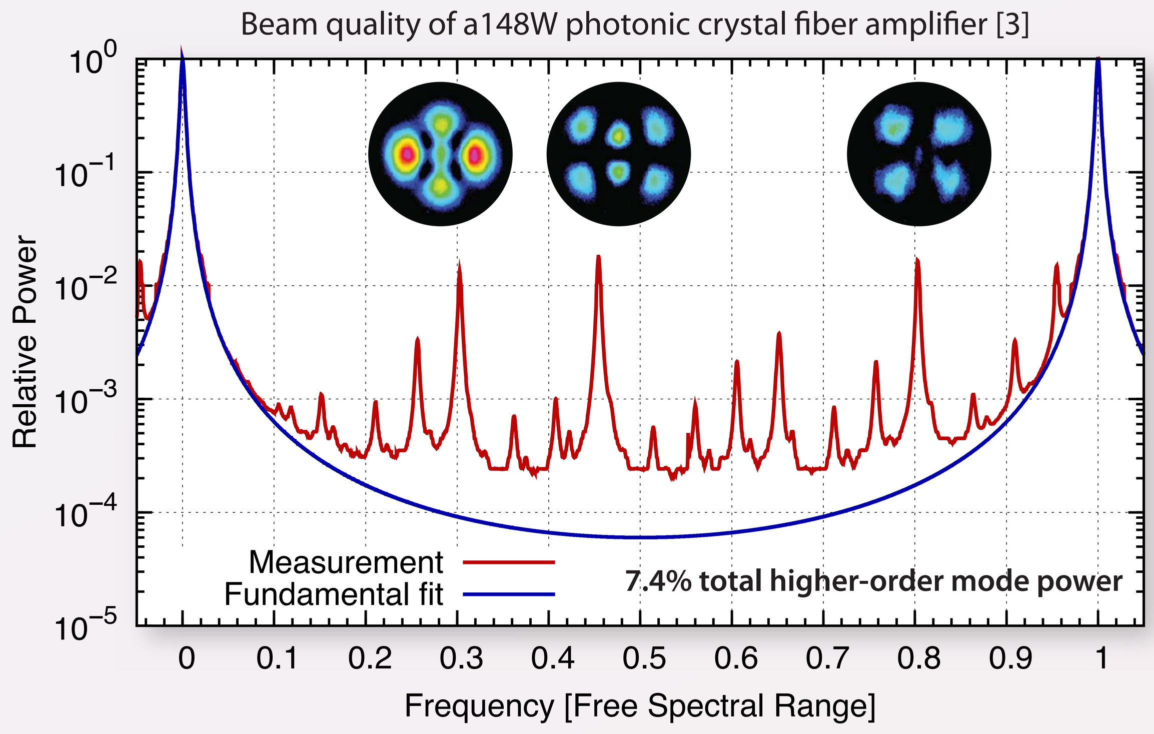
Down to relative TEM mode powers of

$TEM_{lm} < 10^{-5} TEM_{00}$

Down to total higher-order mode power of

$\Sigma TEM_{lm} < 0.18\% TEM_{00}$

Beam quality of a148W photonic crystal fiber amplifier [3]

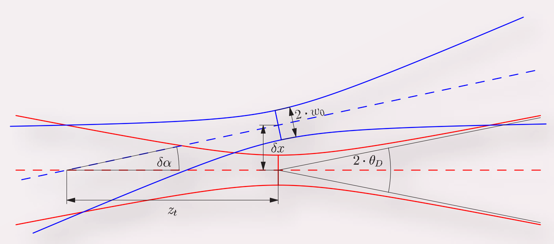


Pointing Noise

- Measured with differential wavefront sensing (DWS) technique
- Optical ring resonator as pointing reference
- Quadrant photodiodes QPD1 and QPD2 used to detect DWS signals
- Mirror mounts with piezo actuators (PZT1, PZT2) used to stabilize beam pointing

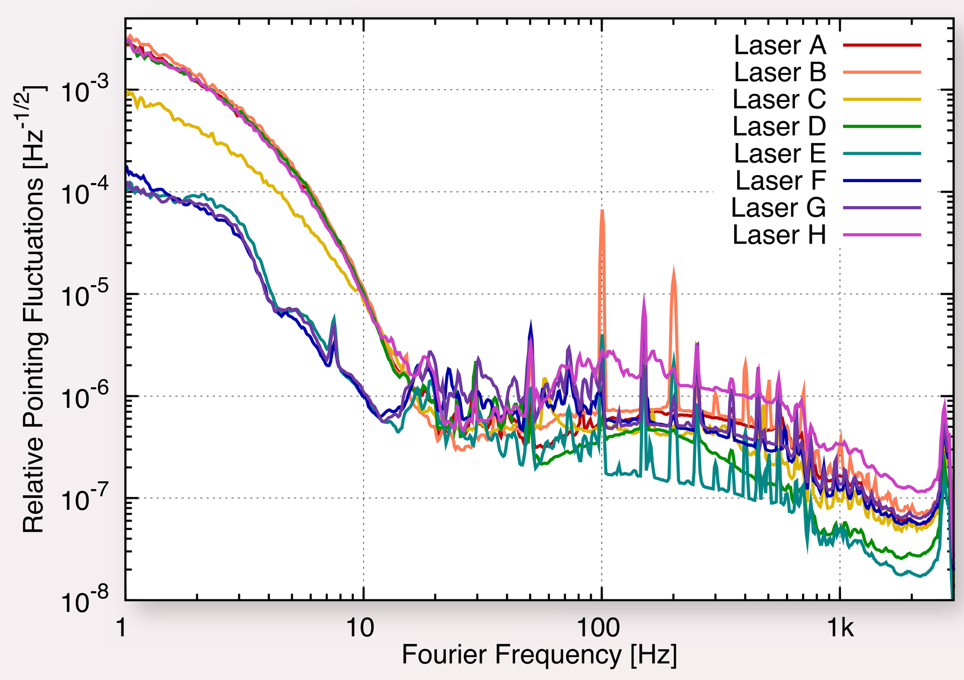
Relative Pointing

- Measured in a complex dimensionless quantity ε
- Transversal shifts and tilts normalized with beam parameters



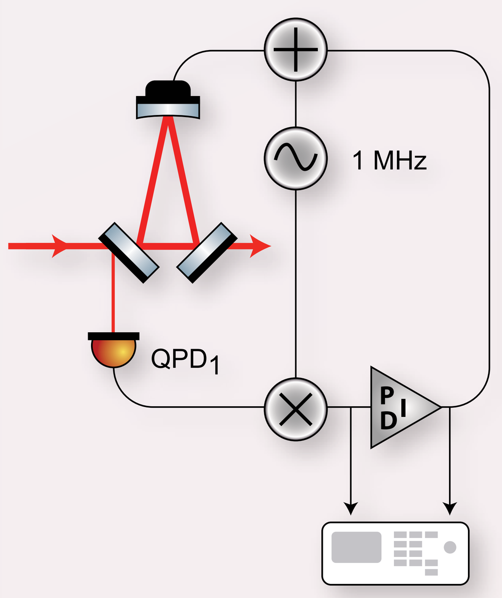
$$\epsilon = \frac{\delta x}{w_0} + i\frac{\delta \alpha}{\theta_D}$$

Pointing noise of 8 different NPROs [2,5]

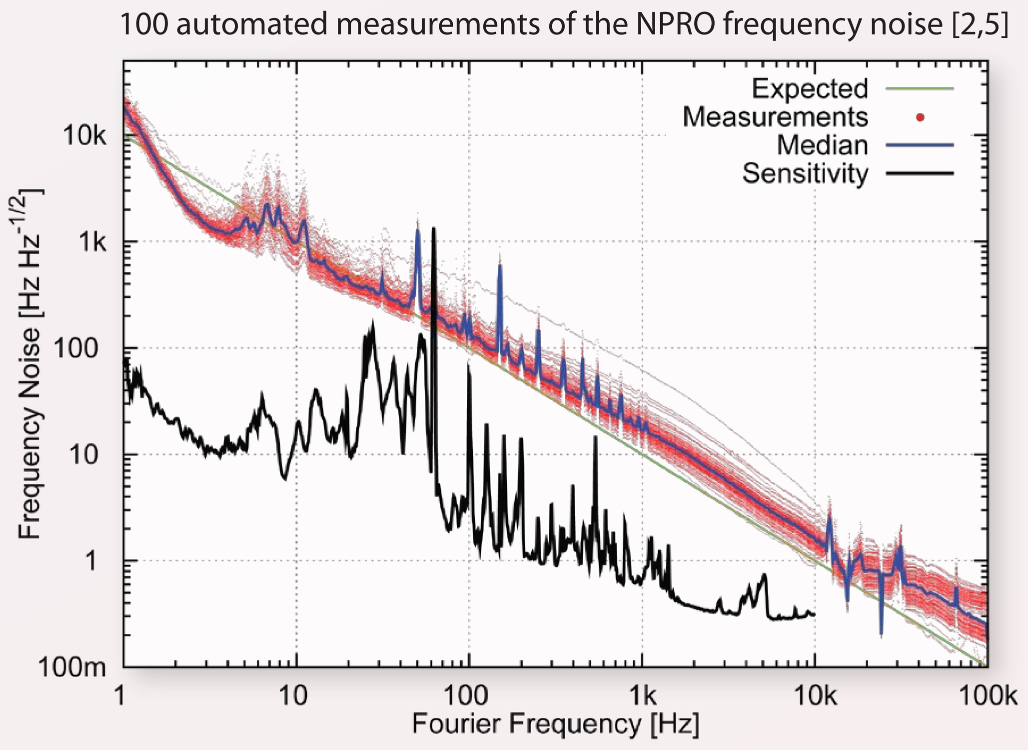


Frequency Noise

- Measured with the optical ring resonator as a frequency reference
- Dither lock at 1 MHz with piezoelectric element
- Resonator finesse of about 356 and free spectral range of 715MHz
- Aluminum tank for acoustic shielding

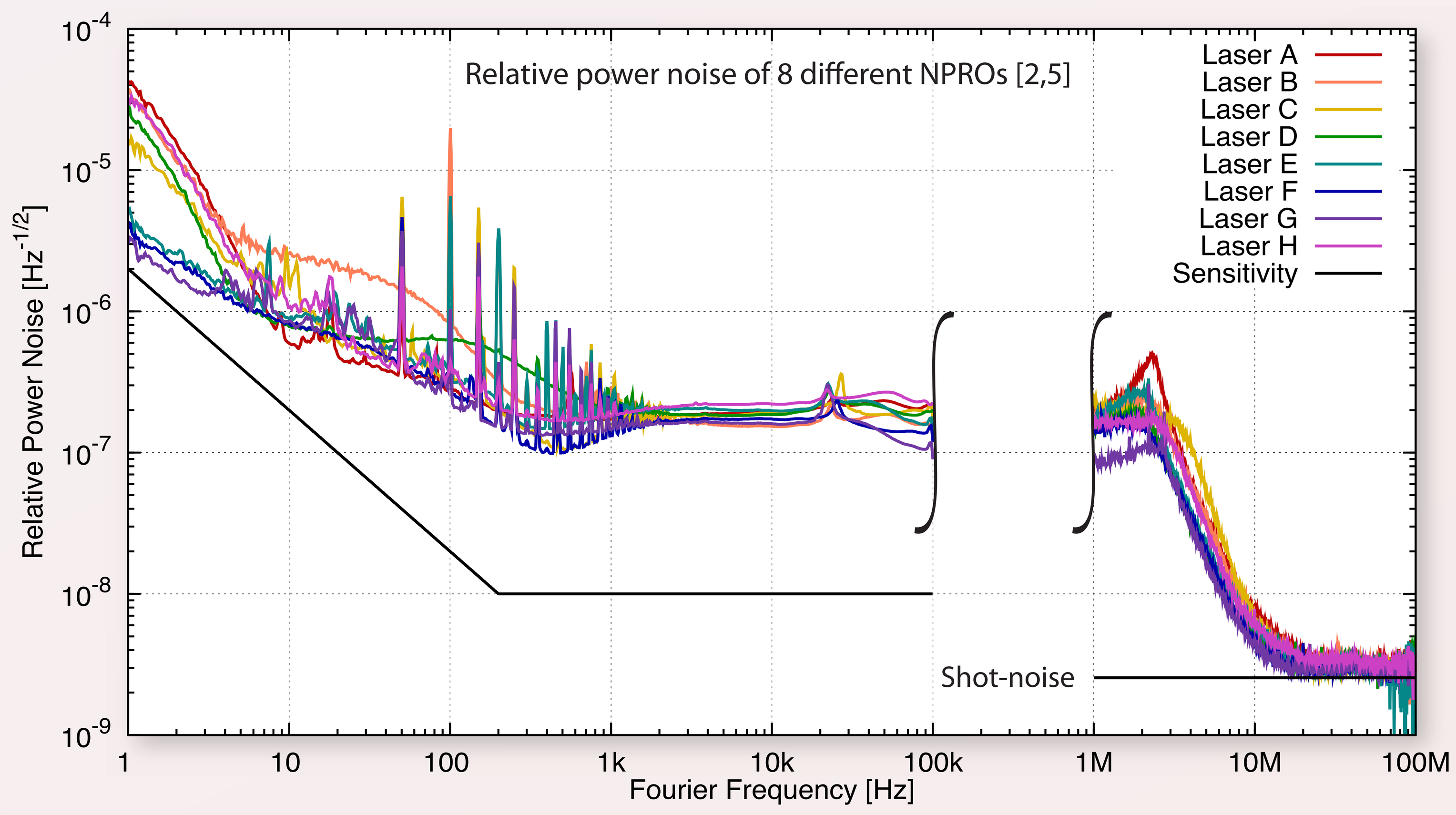


100 automated measurements of the NPRO frequency noise [2,5]



Power Noise

- Measured with 2mm InGaAs photodiode (RPD), 50mA photocurrent
- Low-noise high-current transimpedance amplifier, bandwidth up to 45MHz



Computer Control

- Diagnostic Breadboard measurements are automated and fully computer controlled
- Alignment of the input beam adjustable using mirrors with piezoelectric elements (PZT1, PZT2)
- Mode matching control with two motorized lenses
- Realized two different remote controls:
  - Laboratory computer based on Windows with a A/D and D/A card, long-term characterizations [2] of an NPRO realized with this system
  - Computer system based on a real-time Linux operating system, analog feedback control loops replaced with digital ones

References

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