Optical Turbulence in a Spinning Pipe Gas Lens

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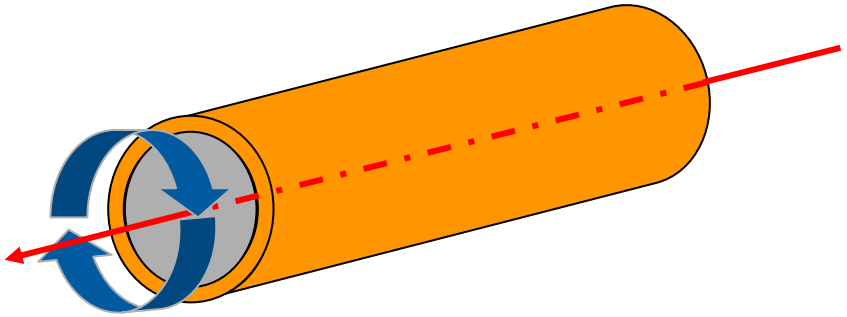
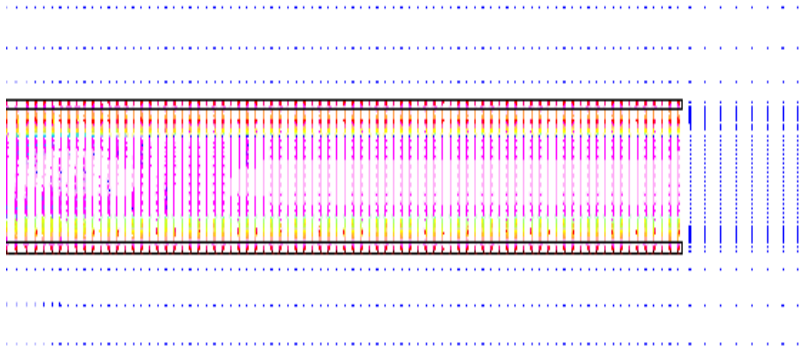
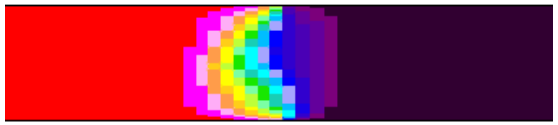
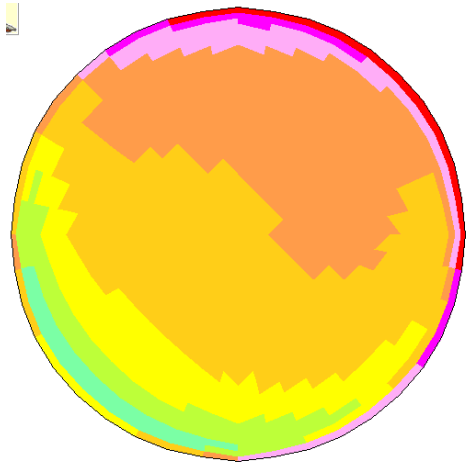
Spinning Pipe Gas Lens - Model



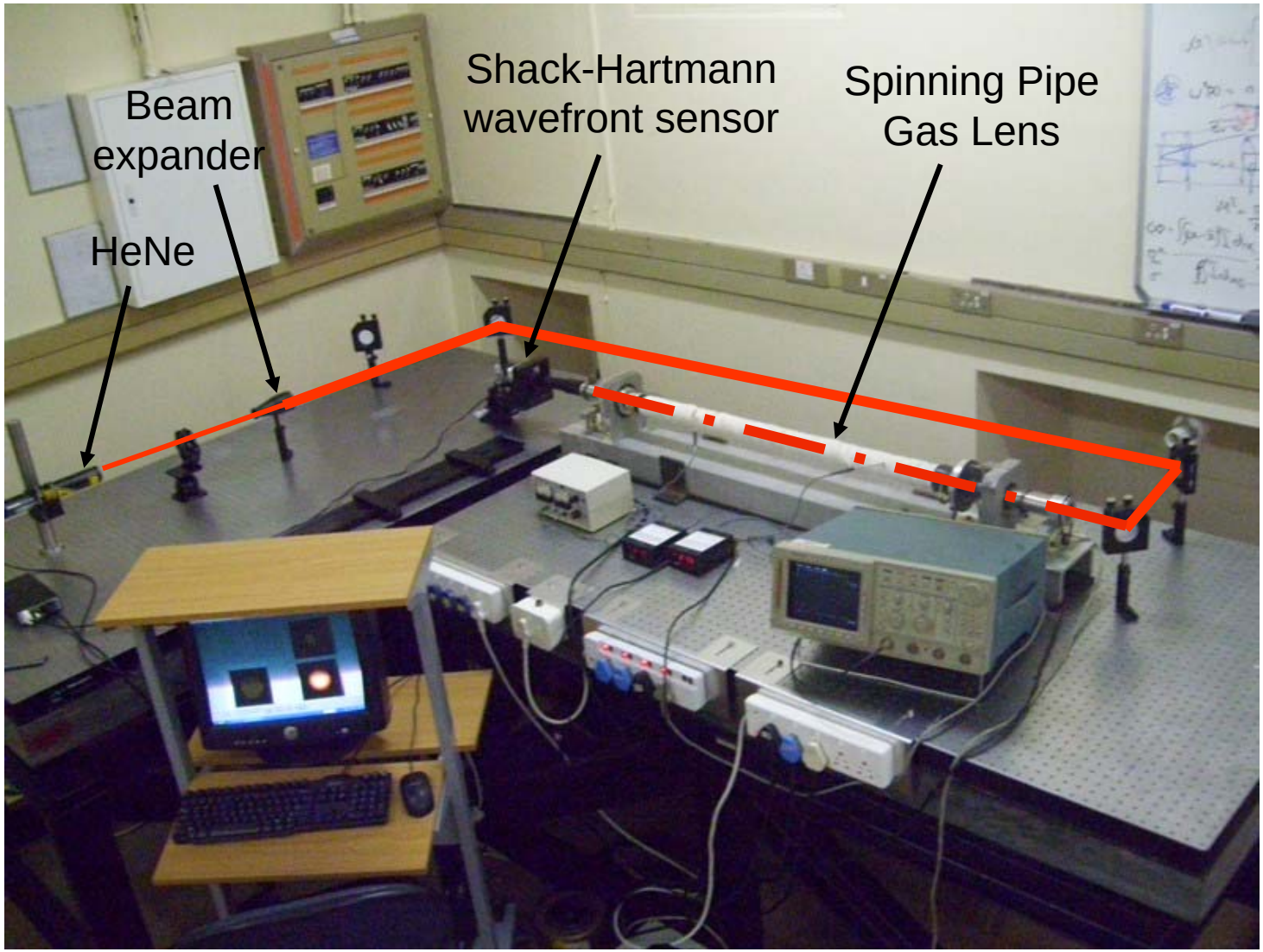


- Spinning pipe schematic
- Velocity distribution



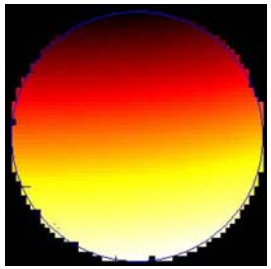


- Density longitudinal cross-section
- Density transverse cross-section

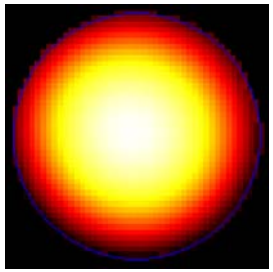

Beam
expander
HeNe
Shack-Hartmann
wavefront sensor
Spinning Pipe
Gas Lens

Spinning Pipe Gas Lens – axial laser beam propagation experiment

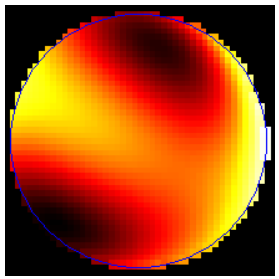
Tilt (heated but stationary)

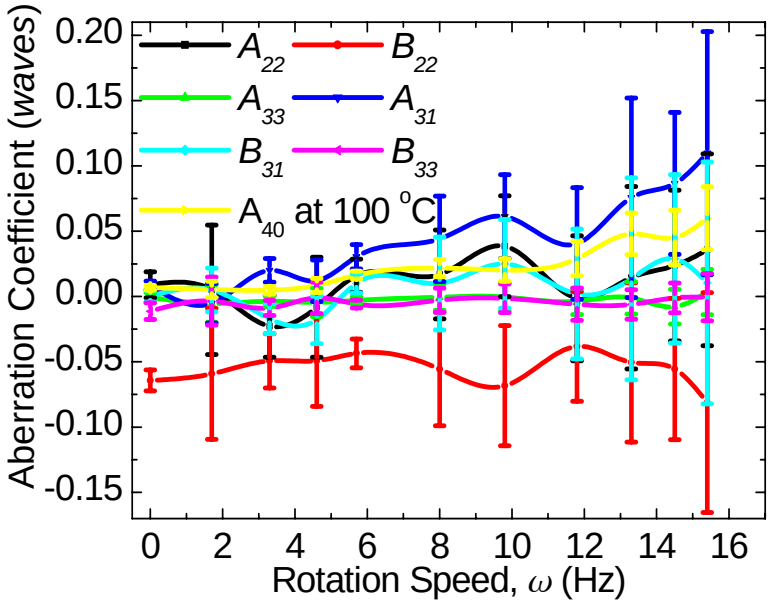


Defocus (steady state rotation)



Phase minus defocus + tilt





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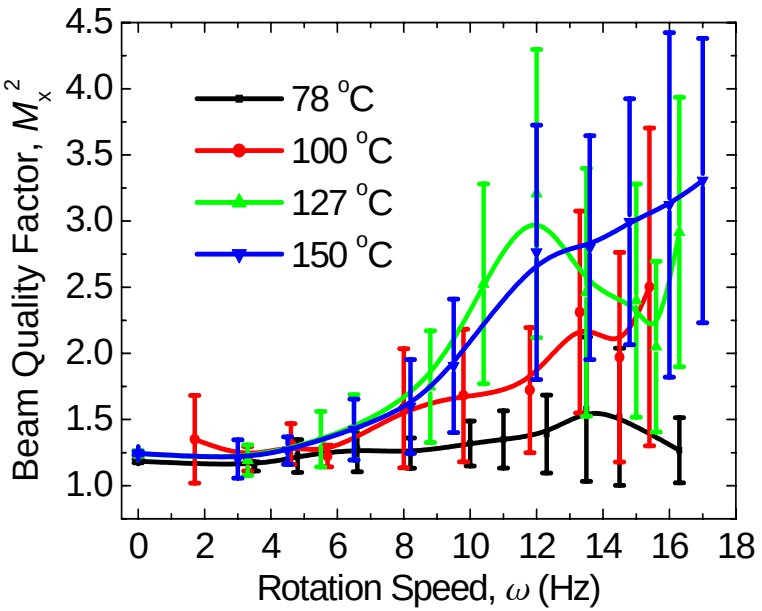
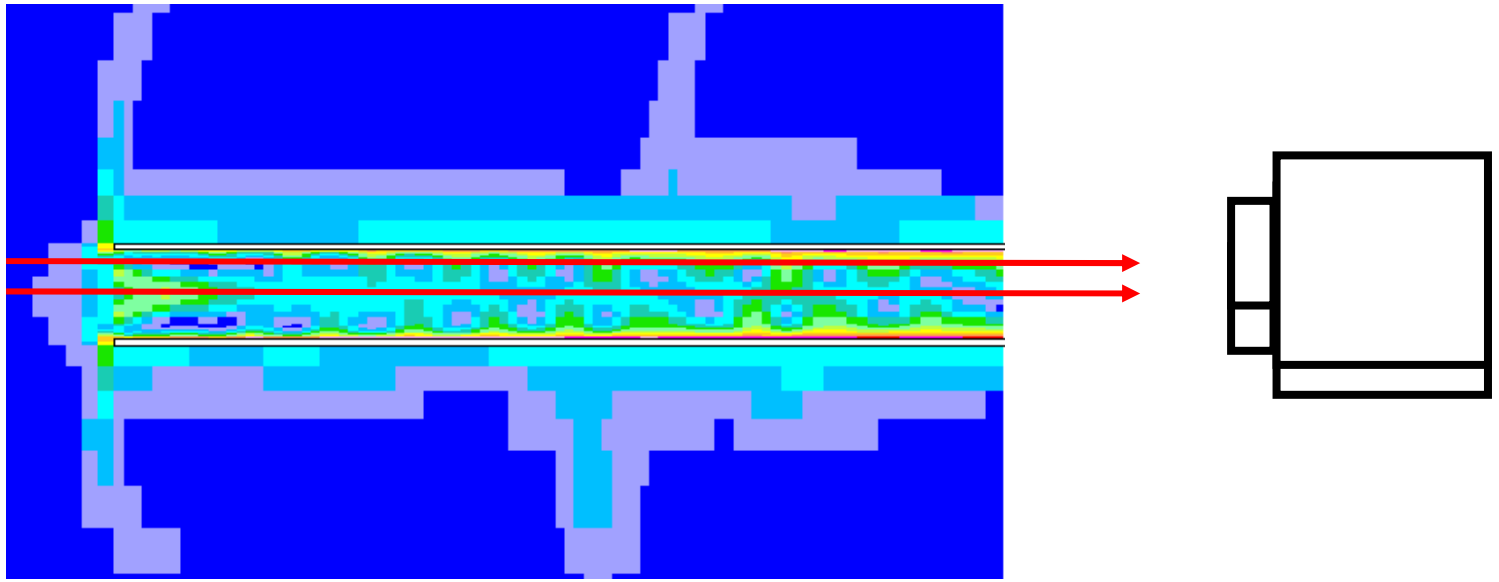


S.A. J. Sc. **104**, 260–264, 2008

Analysis of turbulence in the Spinning Pipe Gas Lens by optical means

- Axial Propagation
- Boundary Layer



Phase Structure Function and Slope Correlation

- Phase Structure Function

$$D_\phi(r) = \left\langle \left[\phi(x+r) - \phi(r)\right]^2 \right\rangle$$

- Kolmogorov model for isotropic and homogeneous turbulence

$$D_\phi(r) = 2.91\left(\frac{2\pi}{\lambda}\right)^2 L\underline{\underline{\mathbf{C_n^2}}} r^{5/3}, \quad \underline{\underline{\mathbf{l_o}}} \le r \le \underline{\underline{\mathbf{L_o}}}$$

Outer Scale

Refractive Index Structure Constant

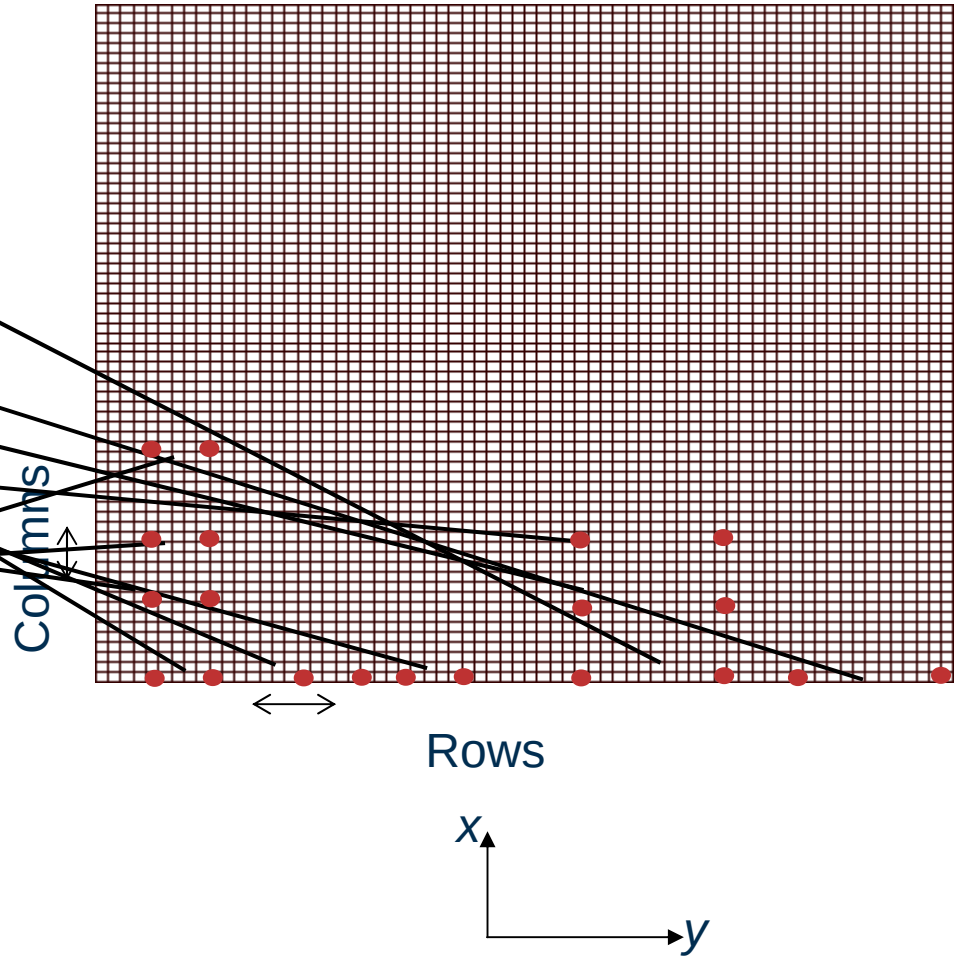
Inner Scale

- Slope Correlation

$$C_s(r) = \langle s(x+r)s(r)\rangle$$

Phase Structure Function and Wavefront Slope Correlation

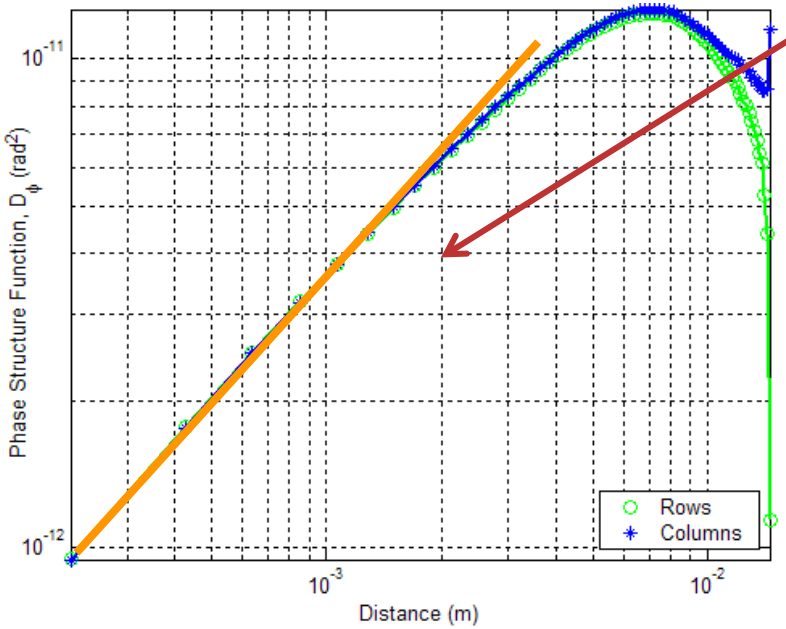
	$D_\phi(r_1)$ or $S_C(r_1)$	$D_\phi(r_2)$ or $S_C(r_2)$
1		
2		
3		
4		
5		
6		
7		
Mean	----------	----------

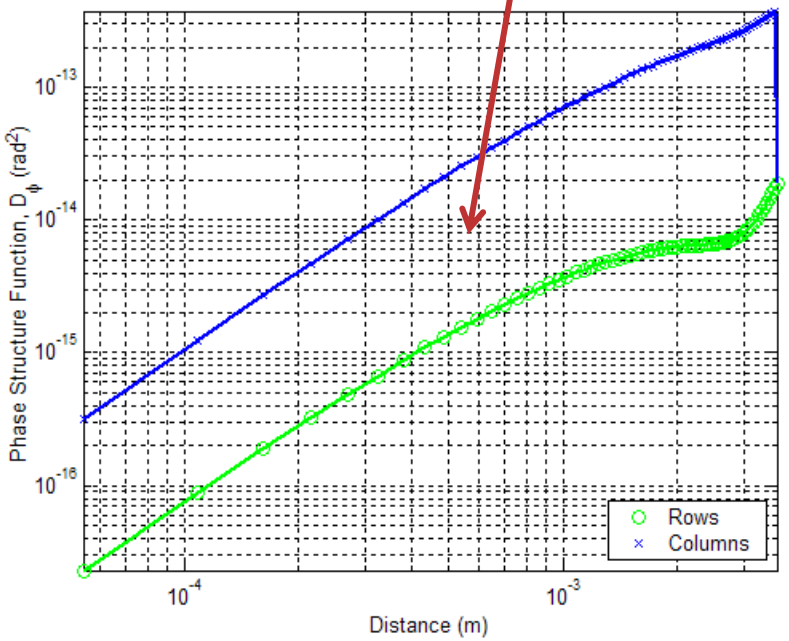


Phase Structure Function

$$\log D_\phi(r) = \frac{5}{3}\log r + \log\left(2.91\left(\frac{2\pi}{\lambda}\right)^2 LC_n^2\right), \quad l_o \le r \le L_o$$

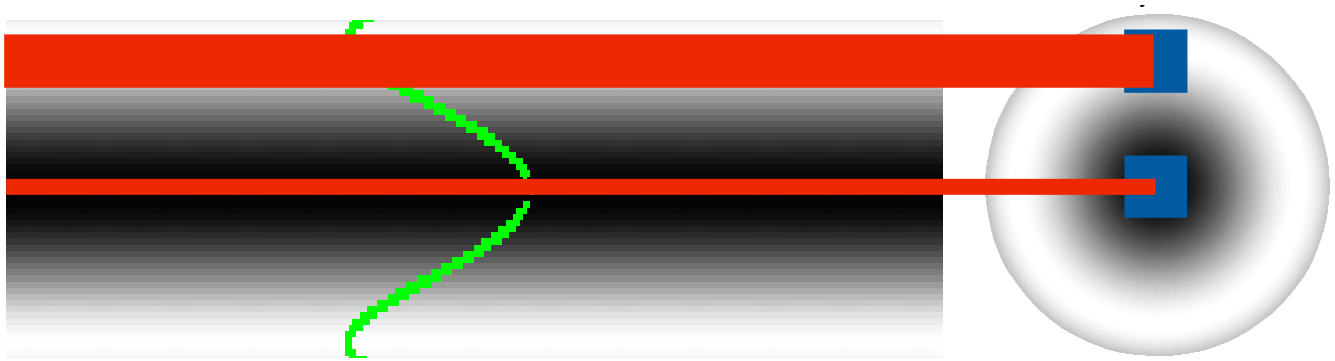
Propagation Path	Axis	Boundary Layer
Isotropy		
Homogeneity		





1. Axial propagation fulfils the conditions for using the Kolmogorov model
2. Boundary layer propagation fails the homogeneity test

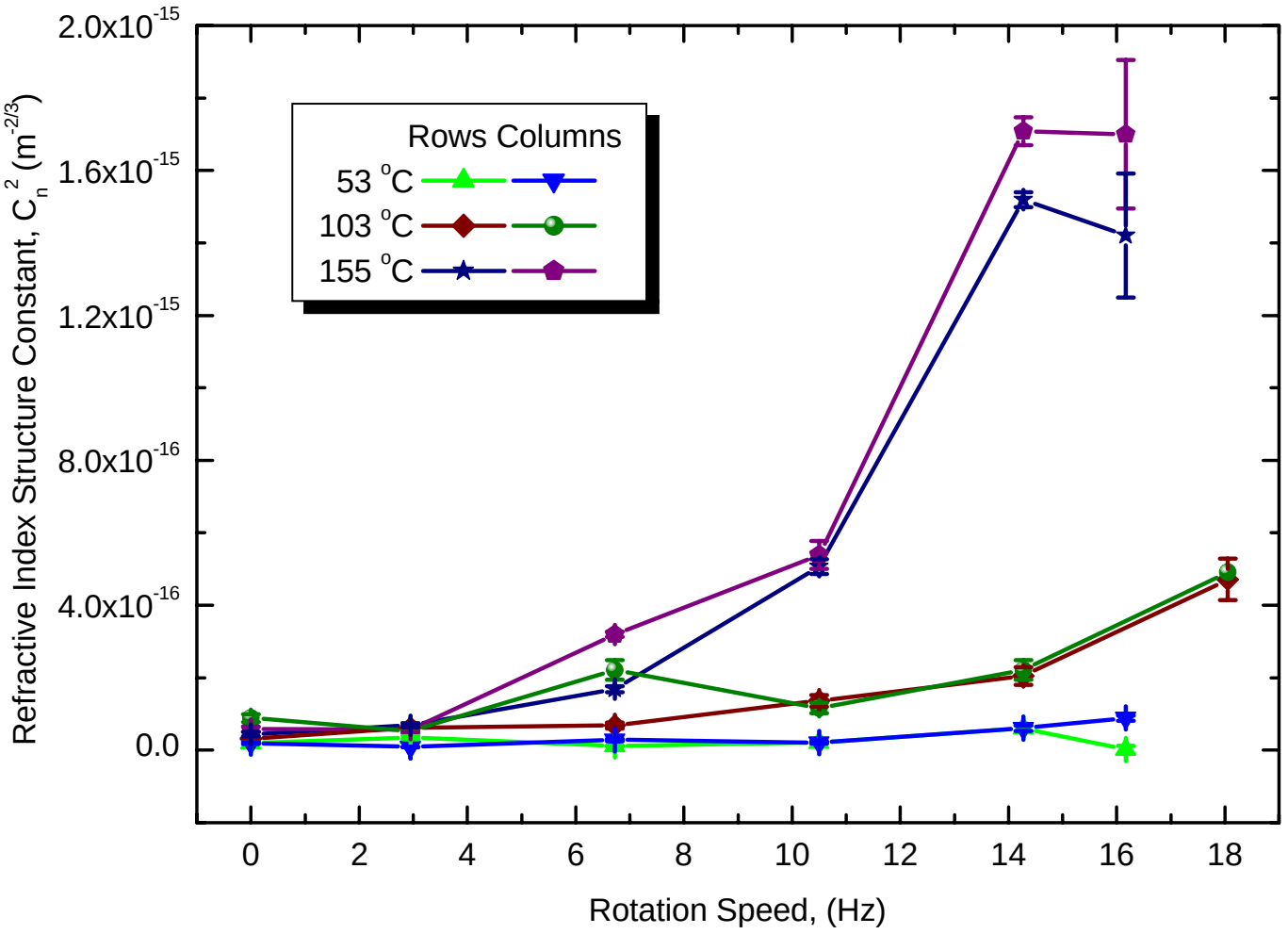
A Schematic Diagram showing Density Distribution in a Spinning Pipe Gas Lens



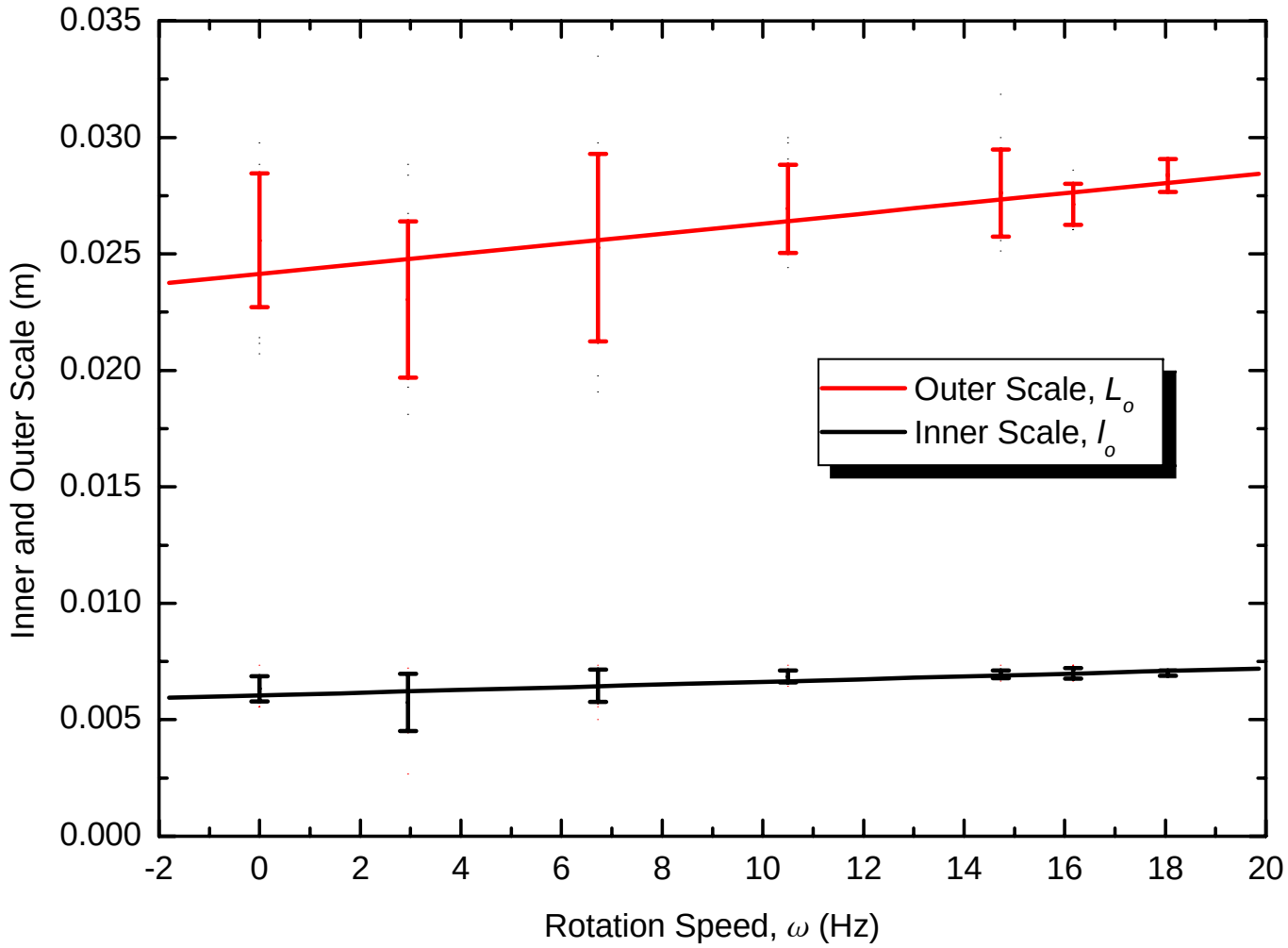
- Detector grid

Axis

Refractive Index Structure Constant

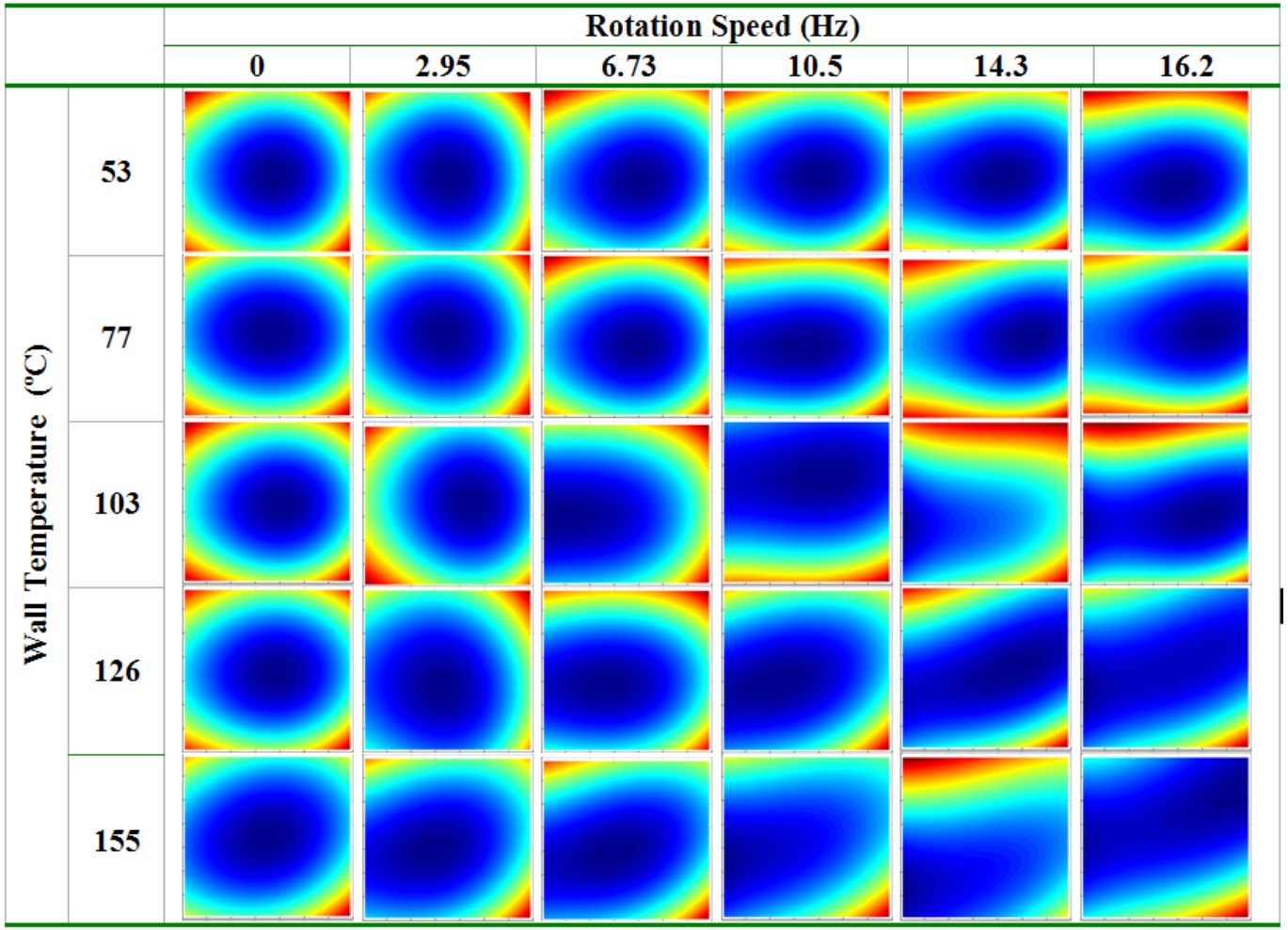


Inner and Outer Scale

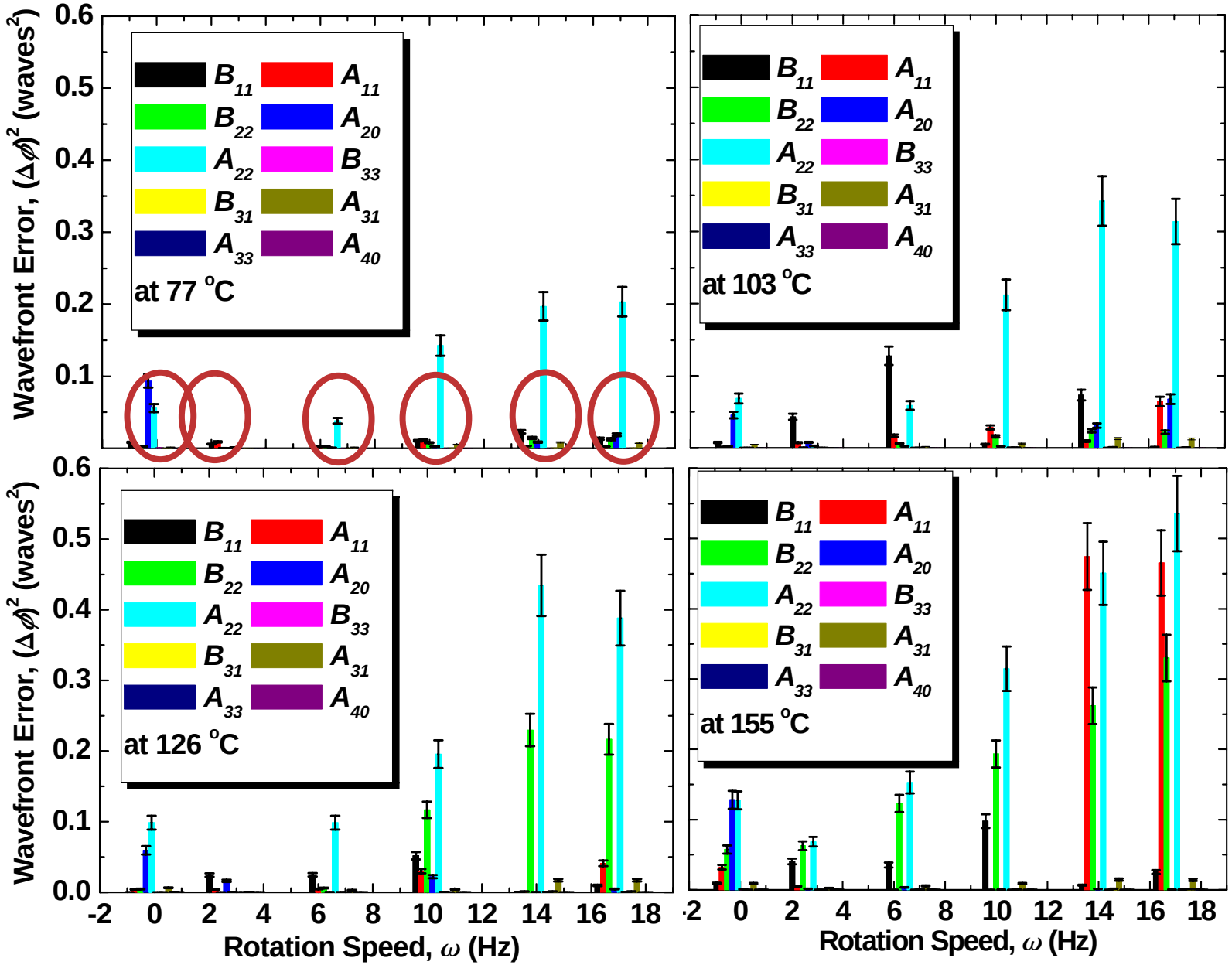


Boundary Layer

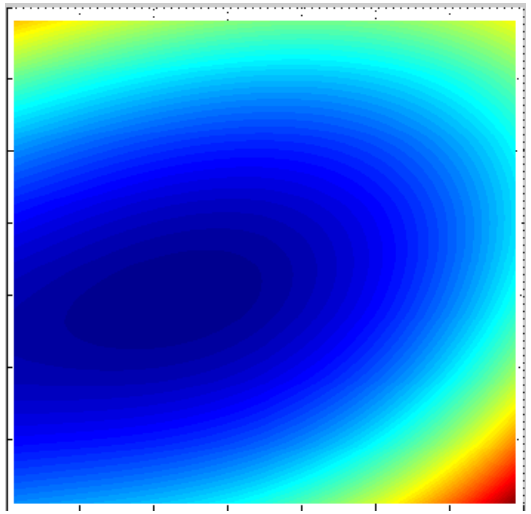
Phase Plots

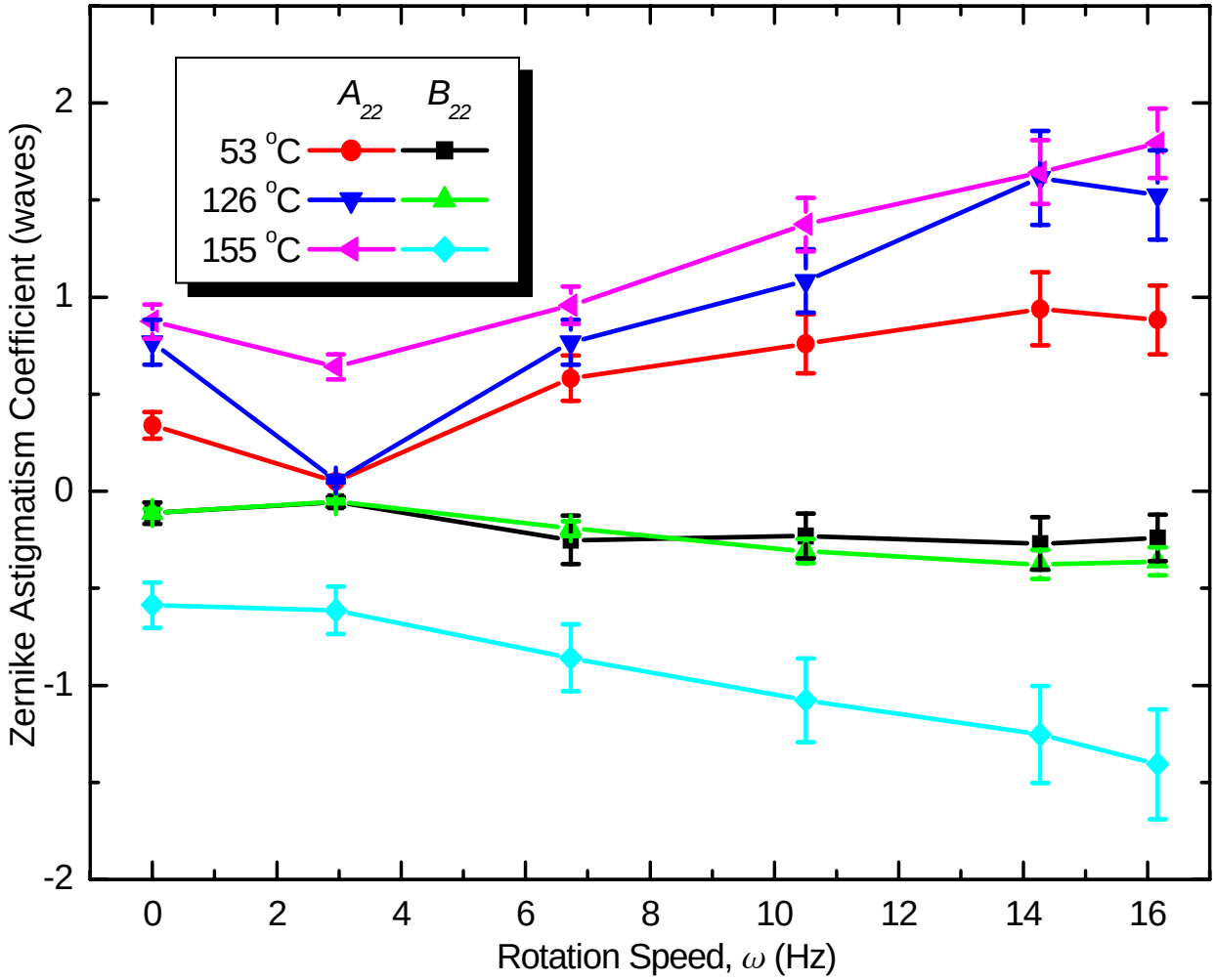

Rotation Speed (Hz)
0
2.95
6.73
10.5
14.3
16.2
Wall Temperature (°C)
53
77
103
126
155

Wavefront Error

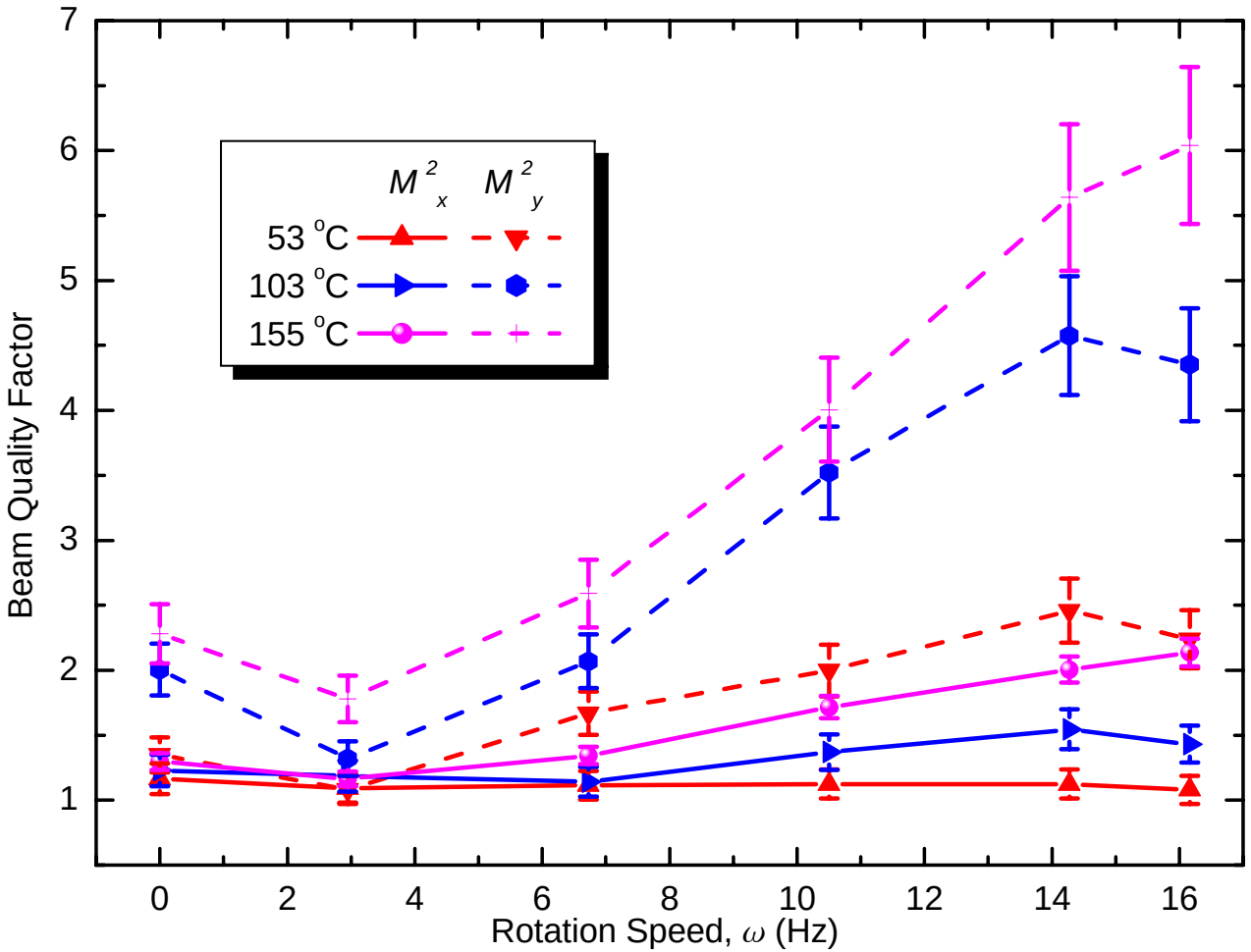


Astigmatism, A_{22} and B_{22}



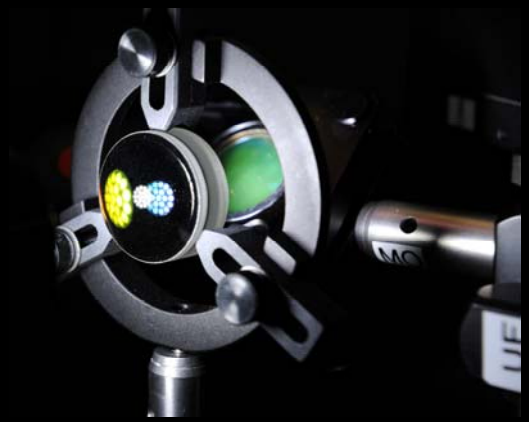


Beam Quality Factor



Concluding remarks

- We have managed to do quantitative analysis of ‘controlled’ turbulence.
- We can control the degree of turbulence by controlling the rotation speed and wall temperature of the spinning pipe gas lens.
- We can potentially do further experiments where we can correct turbulence effects on laser beams in real time.



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