Mode Coupling in Large 2D Complex Plasma Crystals

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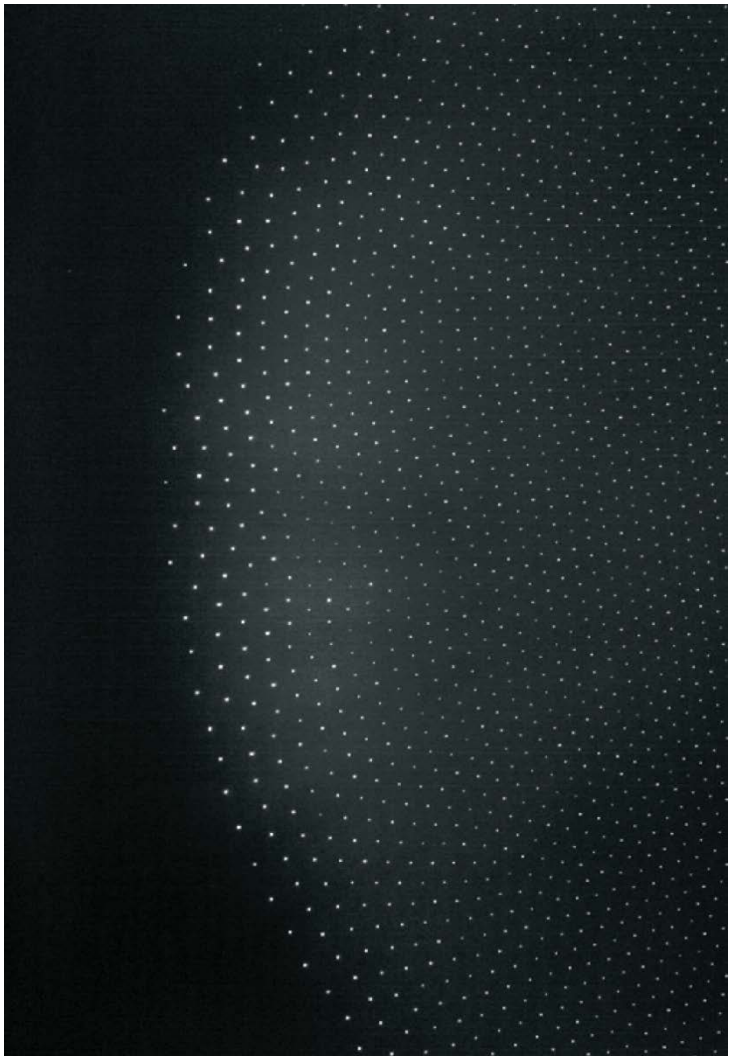
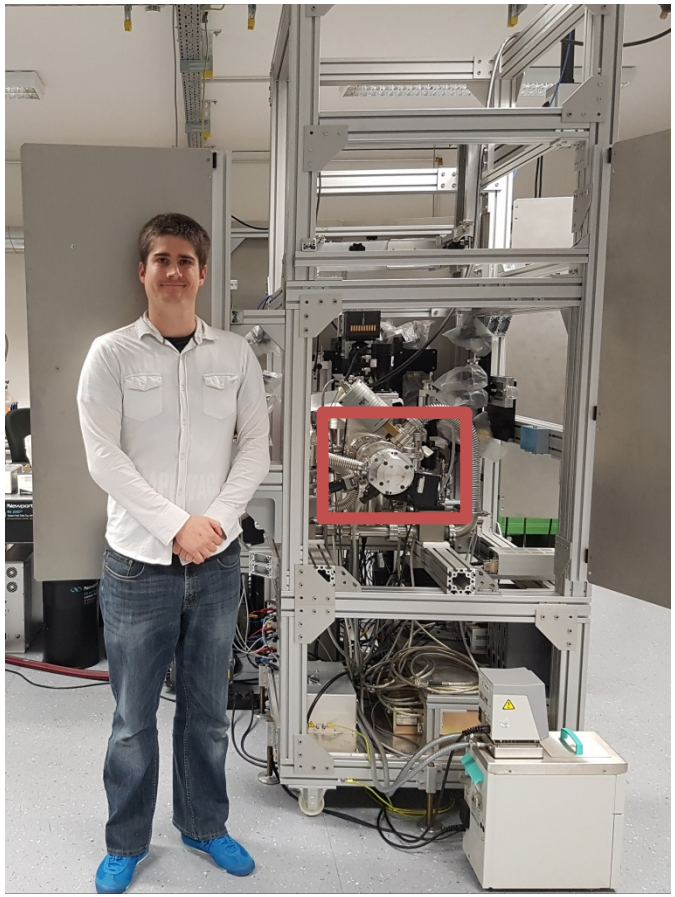
Complex Plasma Research

- Space and lab based experiments
- In labs much research is done in GEC chambers or modified versions thereof
- Crystals limited in practical size to suspensions of ~6 cm diameter
- Minimum pressure of 0.40 Pa for crystals
- Generally around 6000 particles
- Inter-particle spacing varies with radius
- Edge effects
- Large diameter chamber should help improve many of these limitations

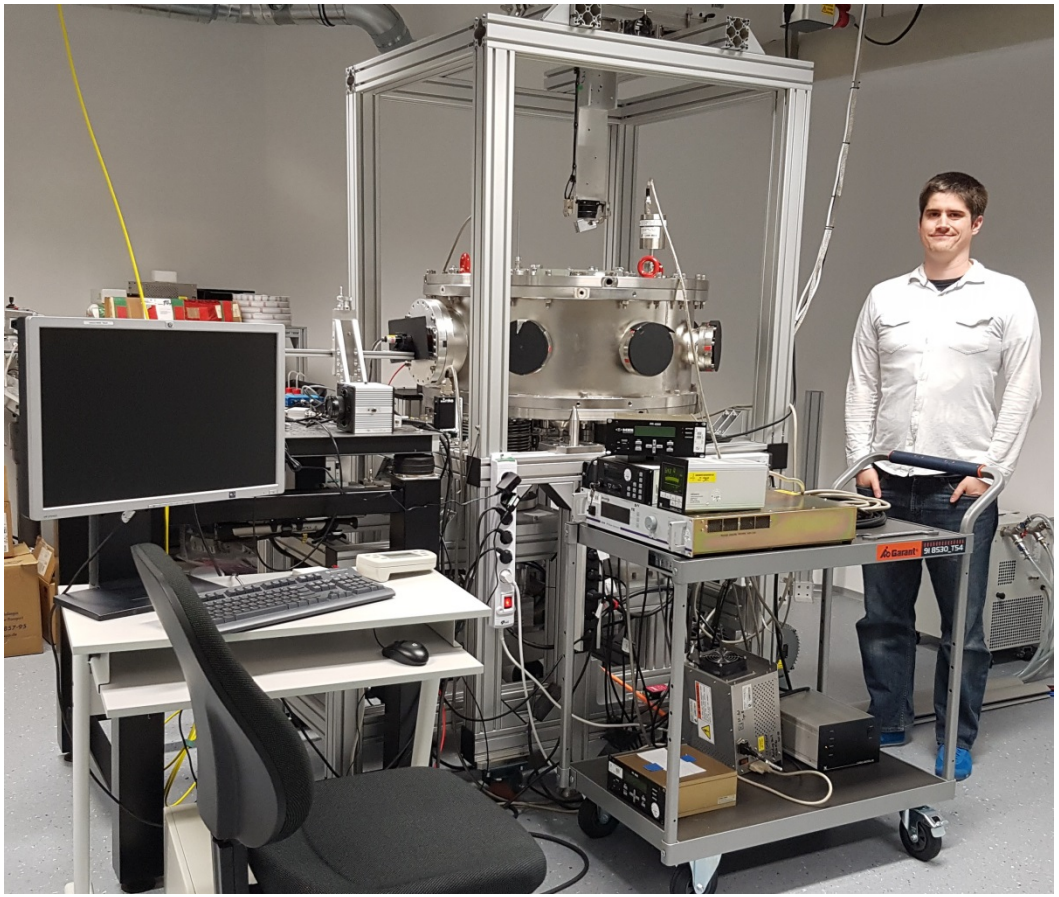


Large Chamber Setup at DLR

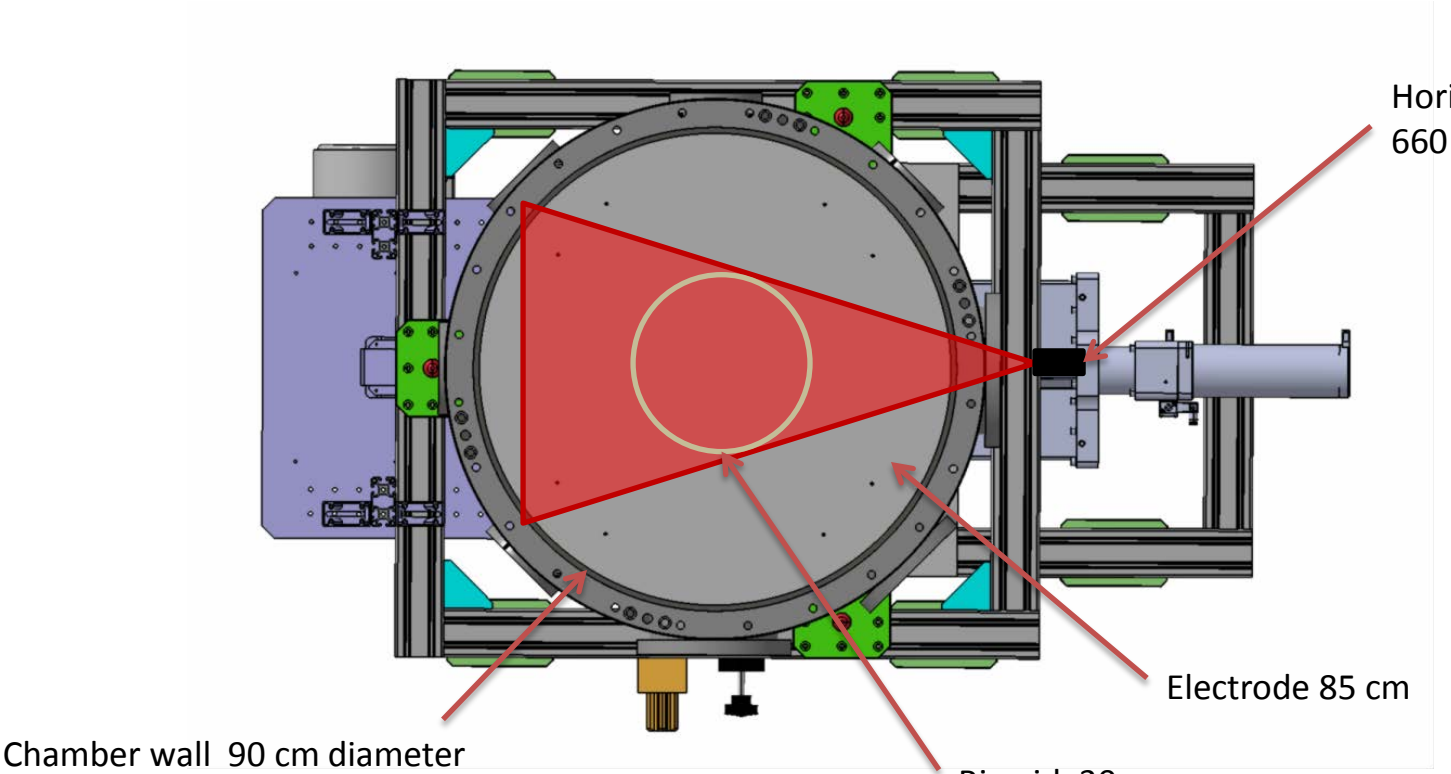
GEC



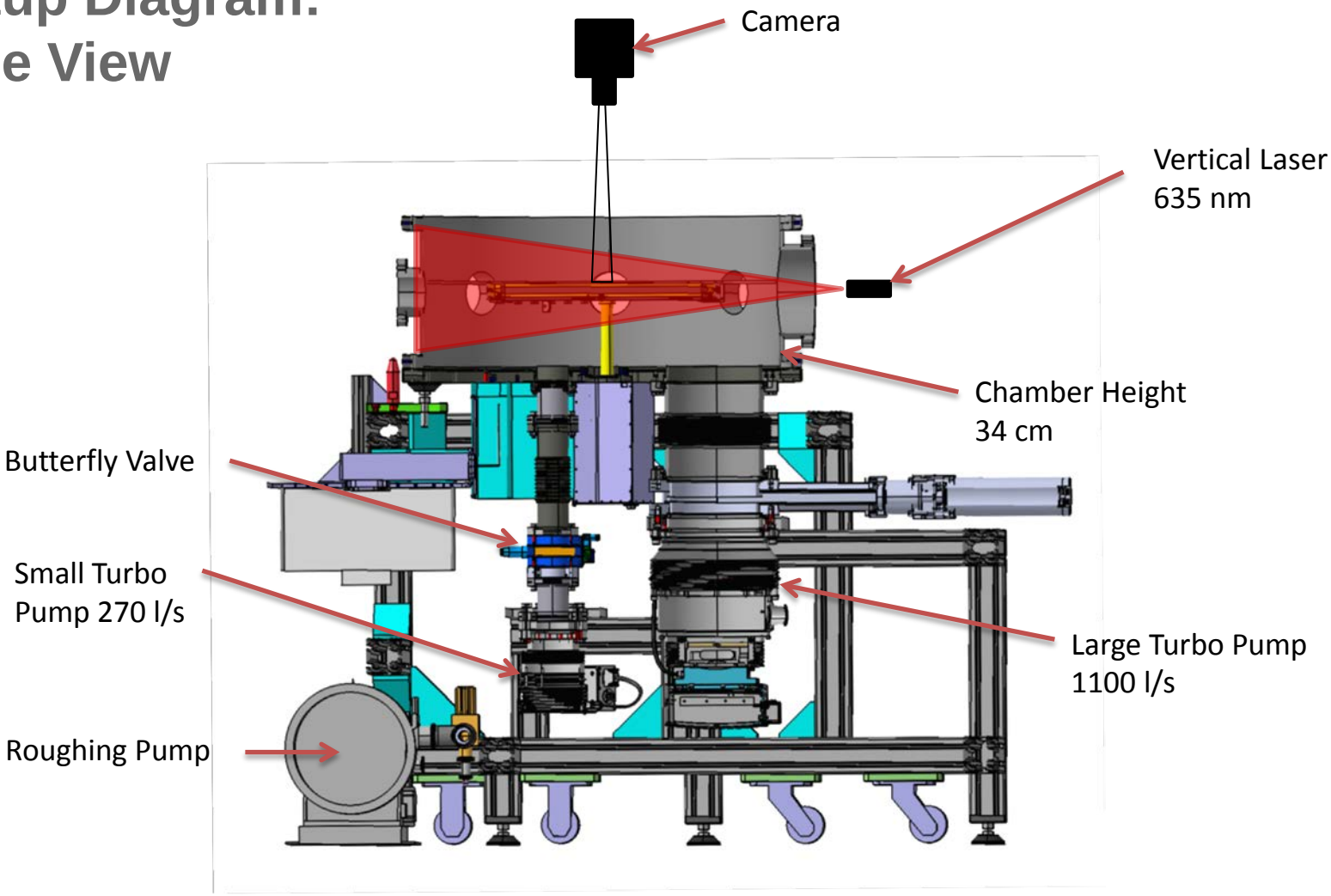
LC



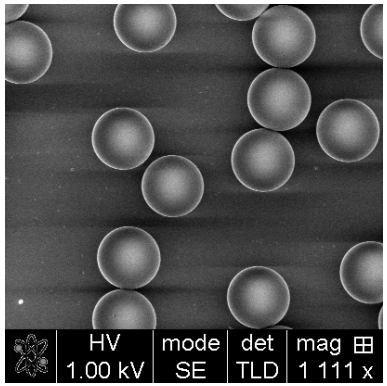
Setup Diagram: Top View



Setup Diagram: Side View



Experimental Parameters



Polymer (MF) microspheres:

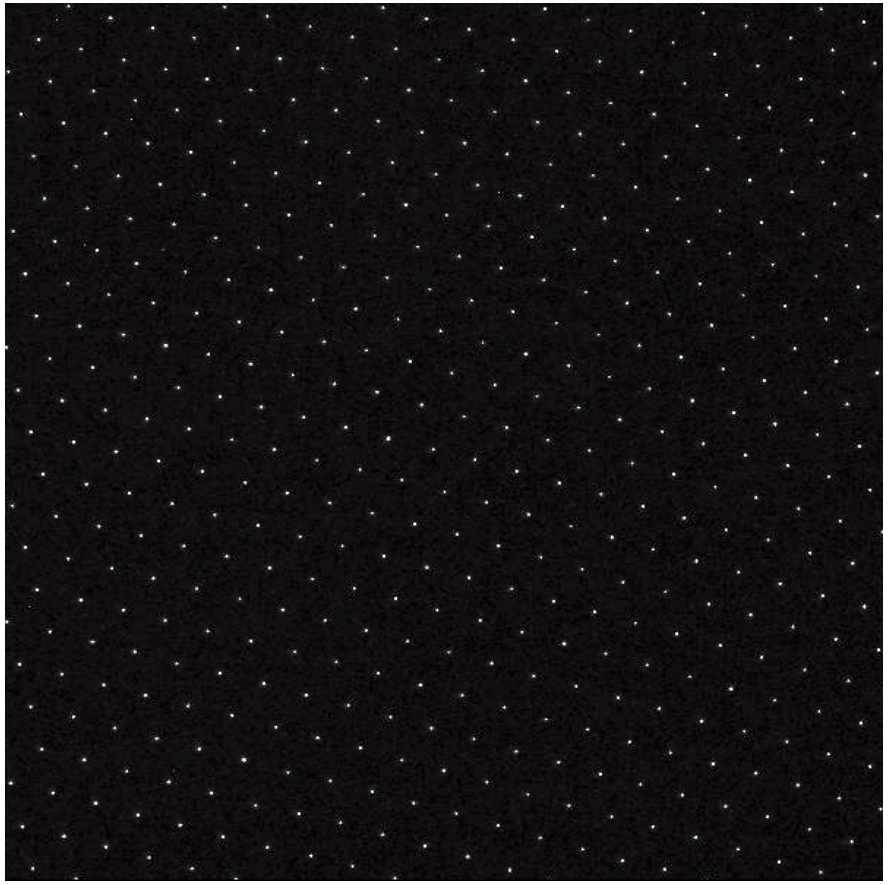
	LC	GEC
Diameter	$d \approx 9\ \mu m$	$d \approx 9\ \mu m$
Charge	$Q \approx -4*10^4\ e$	$Q \approx -2*10^4\ e$
Kappa	$\kappa \approx 1.7$	$\kappa \approx 1.3$
Spacing	$a \approx 1.6$ mm	$a \approx 0.6$ mm
Number	$\approx 15{,}000$	$\approx 6{,}000$

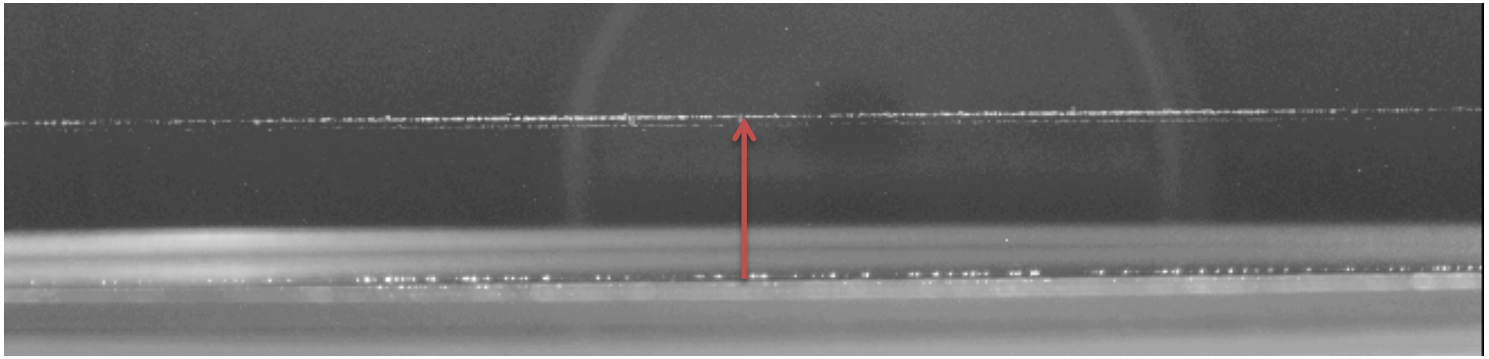
Argon RF plasma:

Pressure	0.10-1.00 Pa	Te	1.5 - 7 eV
RF power	25-200 W	Ne	10^{14} - 10^{15} /m^3
Self Bias	-10- -40 V	Ni	10^{15} - 10^{16} /m^3

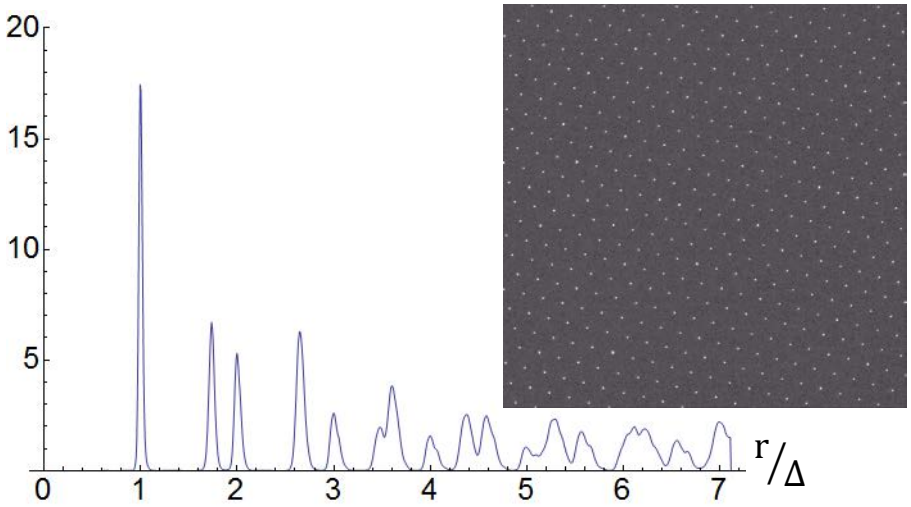
Complex Plasma Introduction

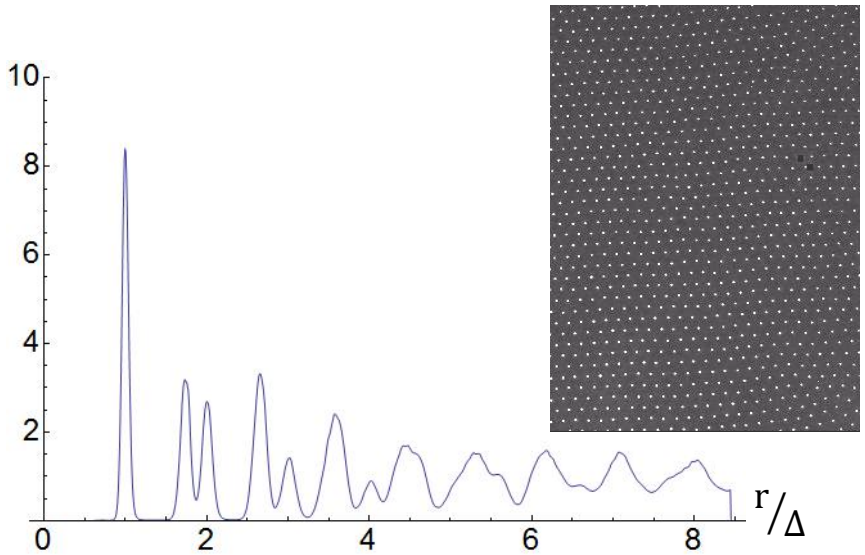
- The inter-particle spacing of the ideal crystal (right) is 1.41mm.
- The dust layer is approximately 1.5 cm above the electrode
- We see that for about 15 cm across the center of the cloud it is flat





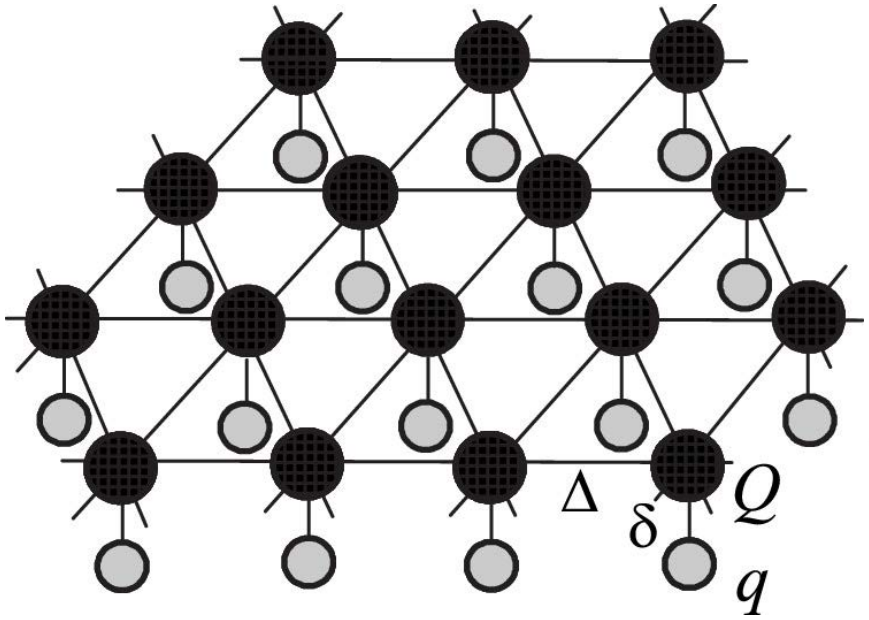
Pair Correlation Function



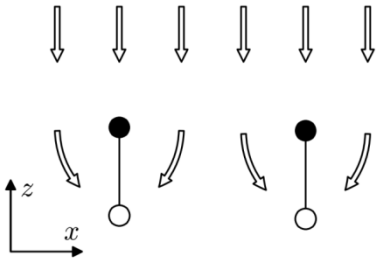


- For the GEC chamber the best values of the first peak are about 8
- The first plot is of the LC experiment with the highest peak (~17), 150 W RF power and 0.40 Pa pressure
- The second is for the LC experiment at 150 W and 0.15 Pa which is analyzed in the rest of the talk

Mode Coupling: Wake Effects

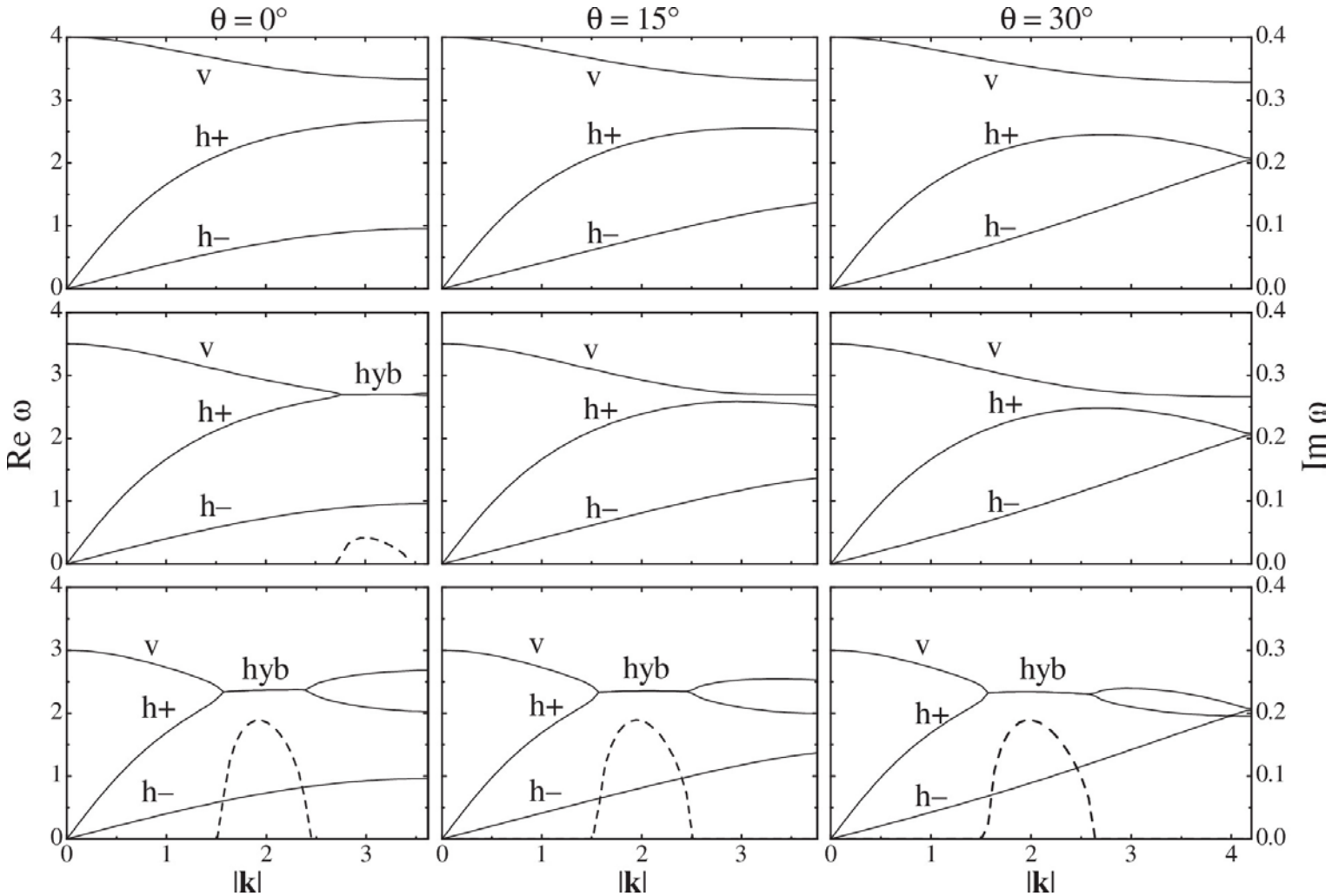


Ion Current



S. Zhdanov, A. Ivlev, G. Morfill, POP 16, 083706

Mode Coupling: Dispersion Relations



S. Zhdanov, A. Ivlev, G. Morfill, POP 16, 083706

Previous Experiments

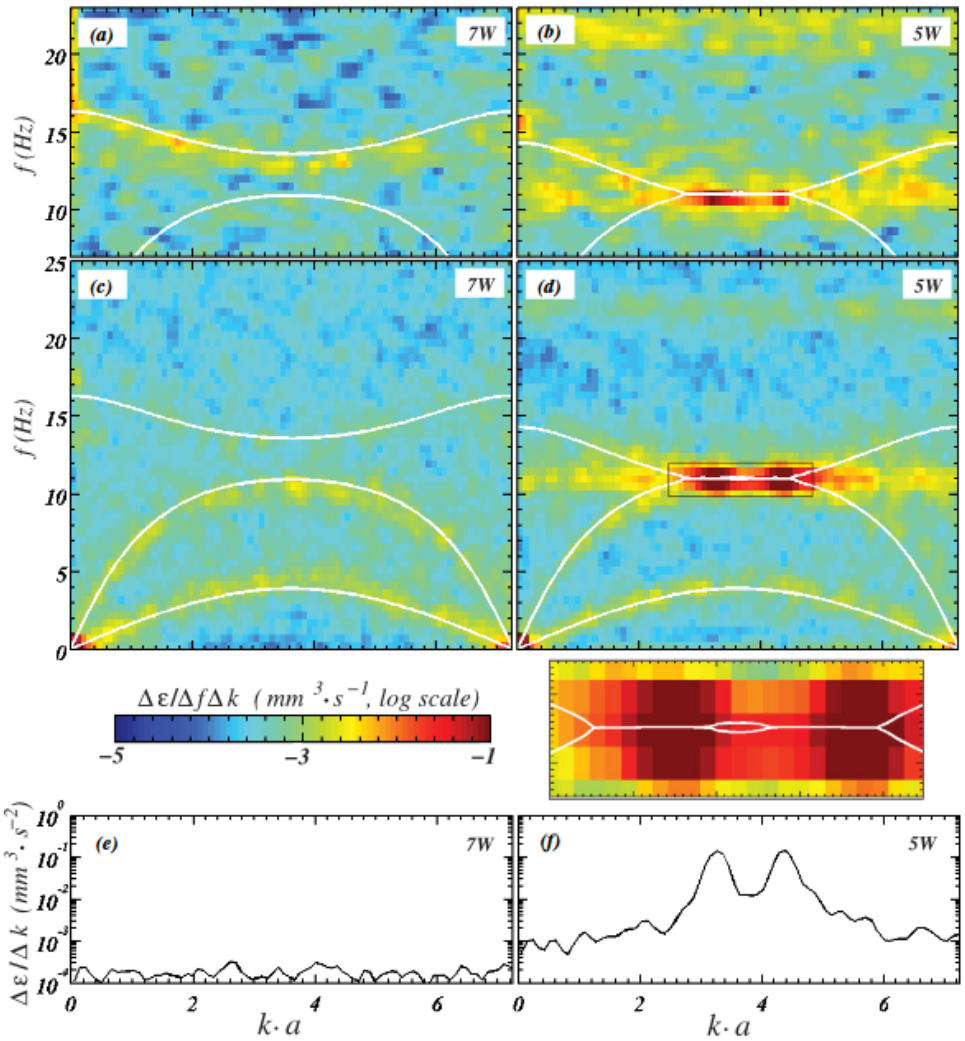
$$\mathbf{V}_{\mathbf{k},\omega}=\frac{2}{L_0 T_0}\sum_{i=0}^{n_l}\sum_{j=0}^{n_t}\mathbf{v}(\mathbf{x},t)\exp(\mathbf{k}\cdot\mathbf{x}-\omega t)\Delta x\Delta t$$

$$\mathrm{I}_{k,\omega} =< |FFT\{\mathbf{V}_k(t)\}|^{\,2} >$$

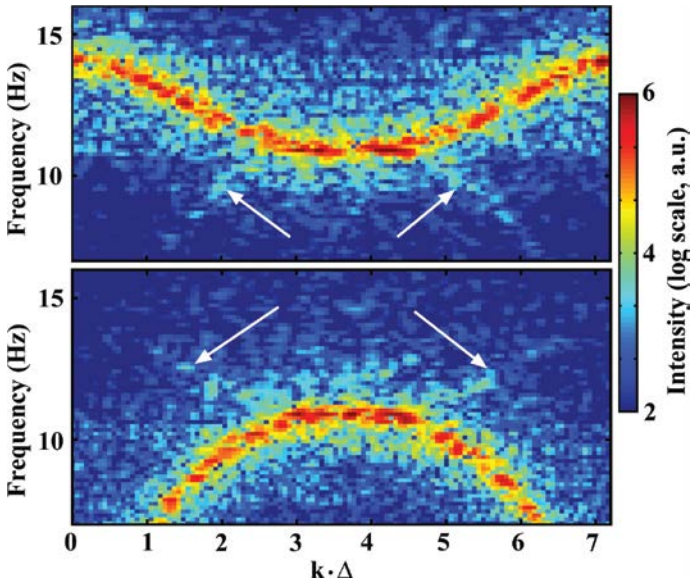
$$C_0 = \sqrt{\frac{Q_{eff}^2}{\varepsilon_0 m a}}$$

$$Q_{eff} = Q_{sim}\sqrt{1-\tilde{q}}$$

$$\tilde{q} = |\,{}^{Q_{wake}}/_{Q_{sim}}\,|$$

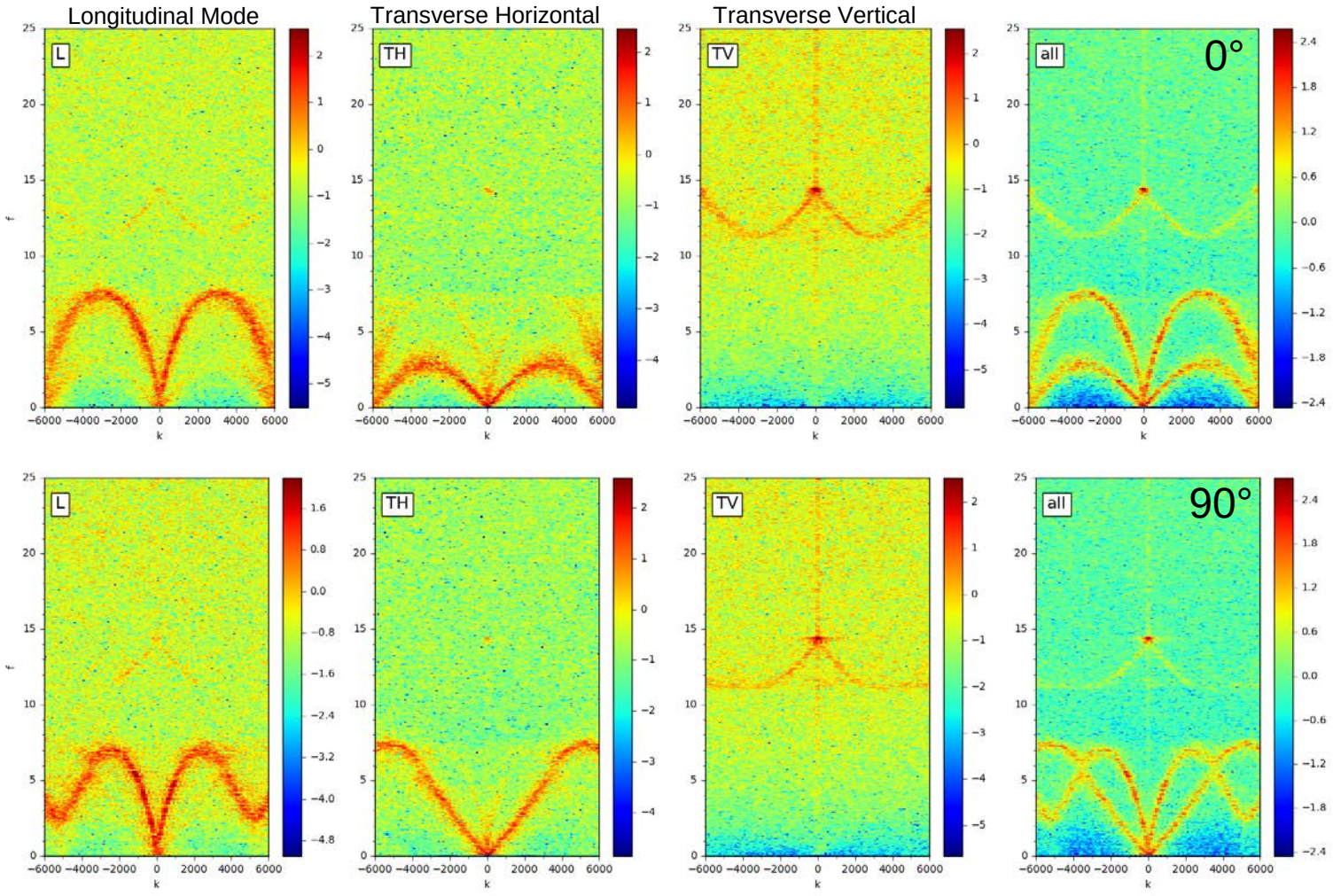


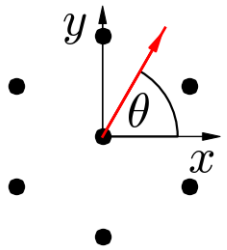
Coueldel et al, PRL 104,195001



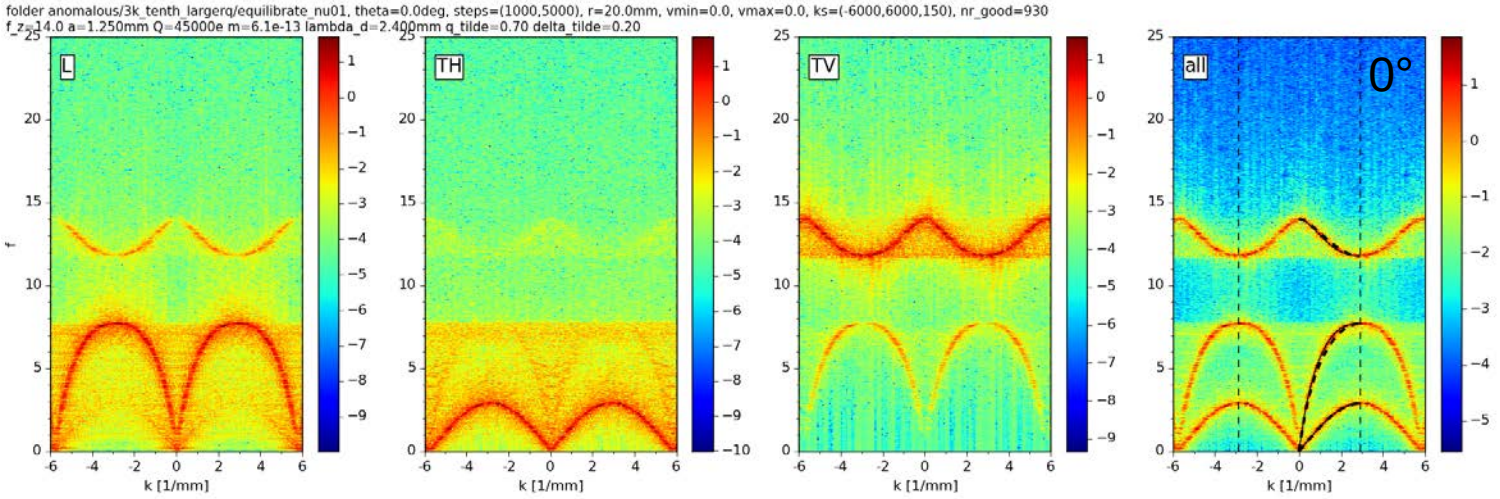
Nunomura et al, PRE 65, 066402

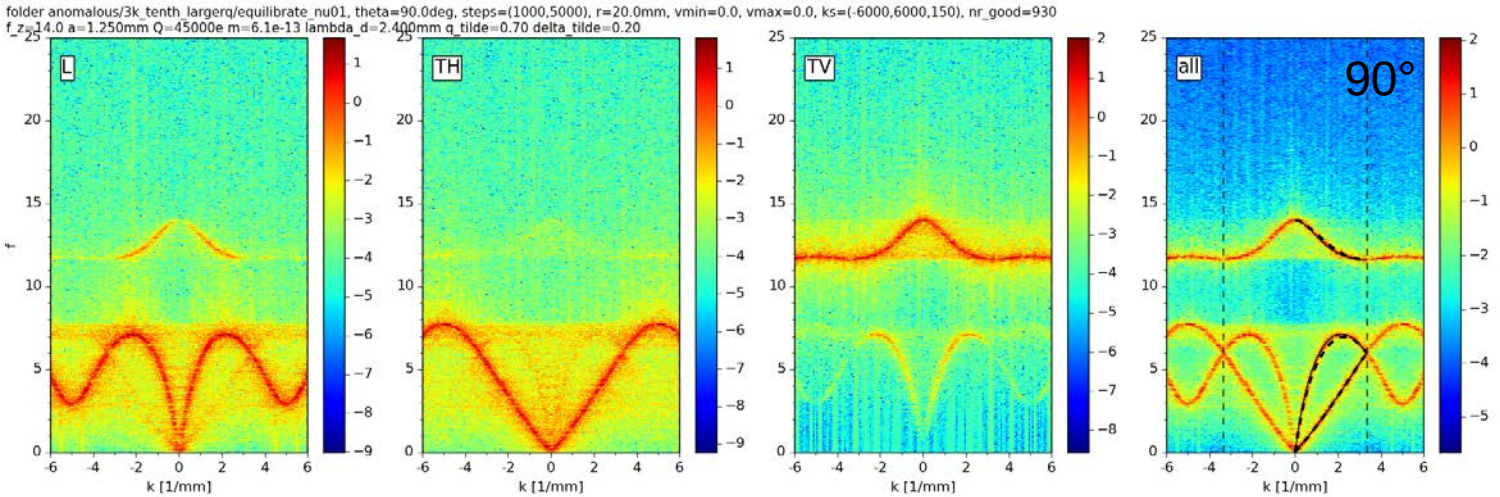
Experimental Spectra

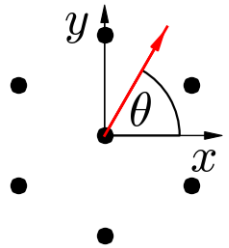




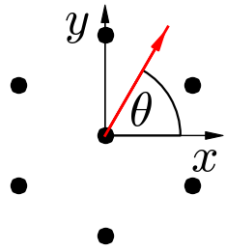
Simulation Spectra

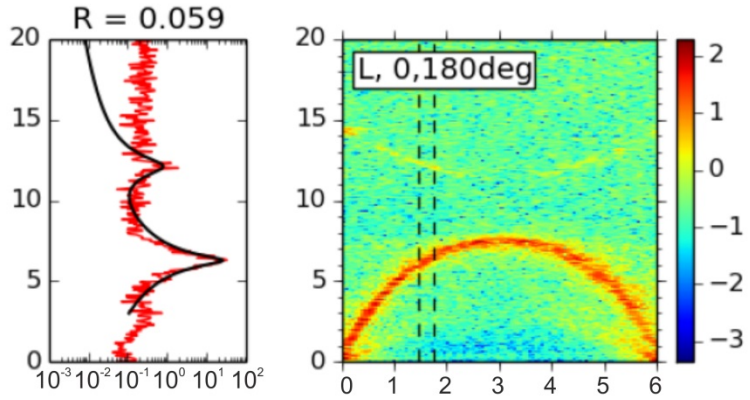


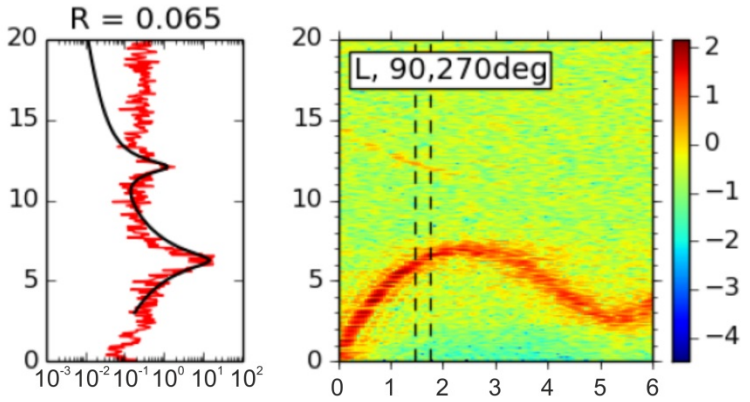


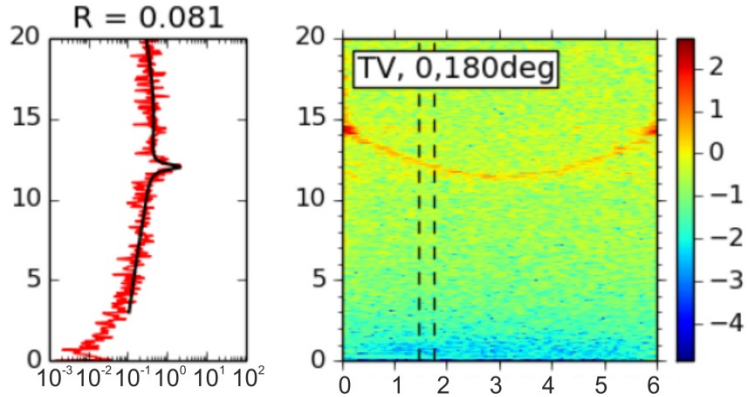


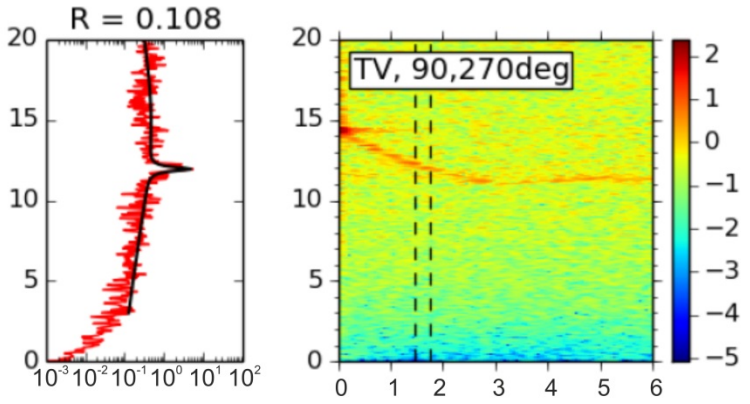
Mixed Polarization Ratio: Exp



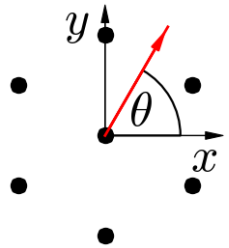


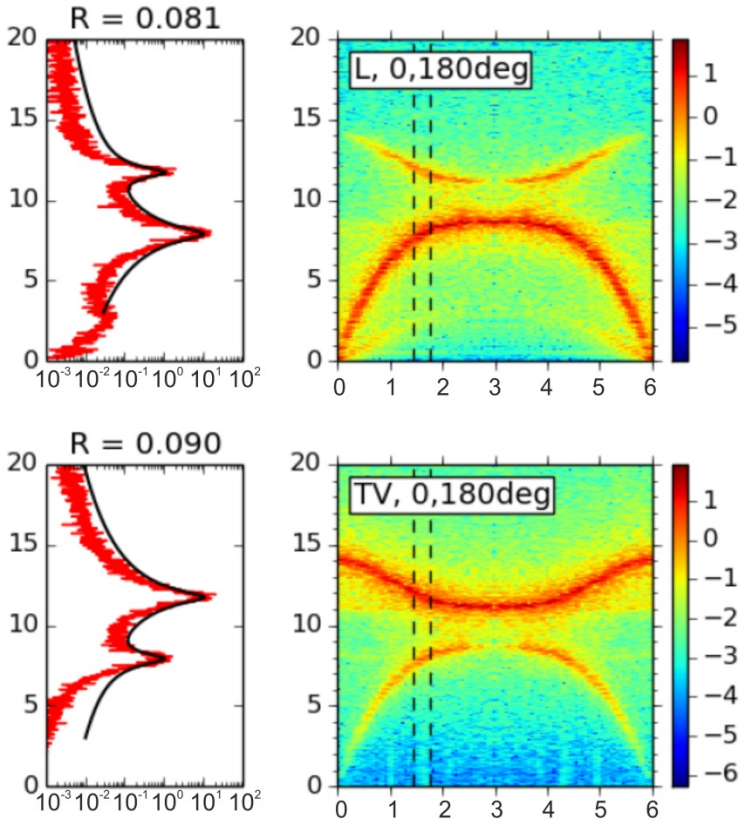


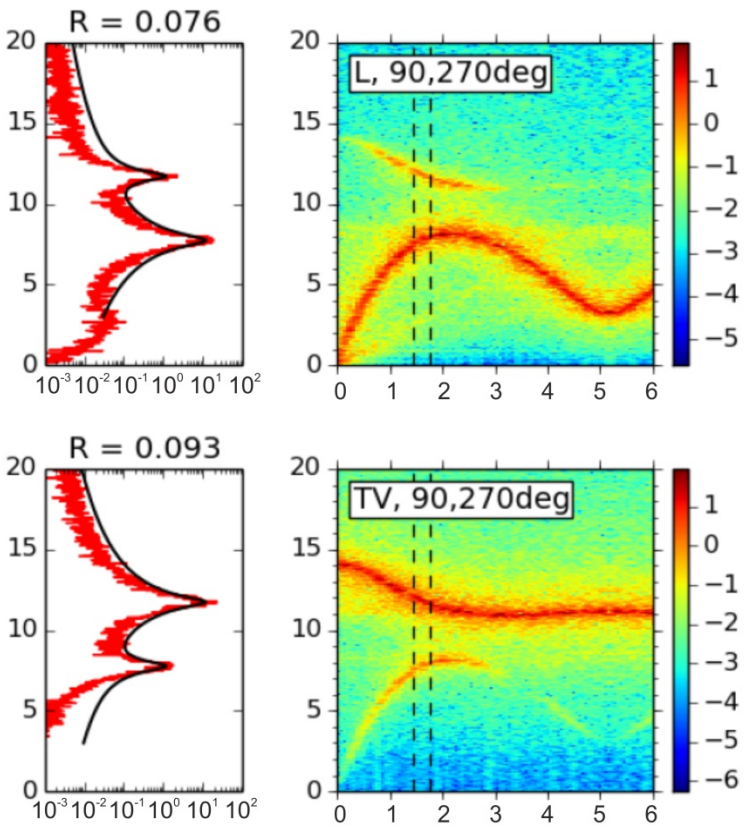




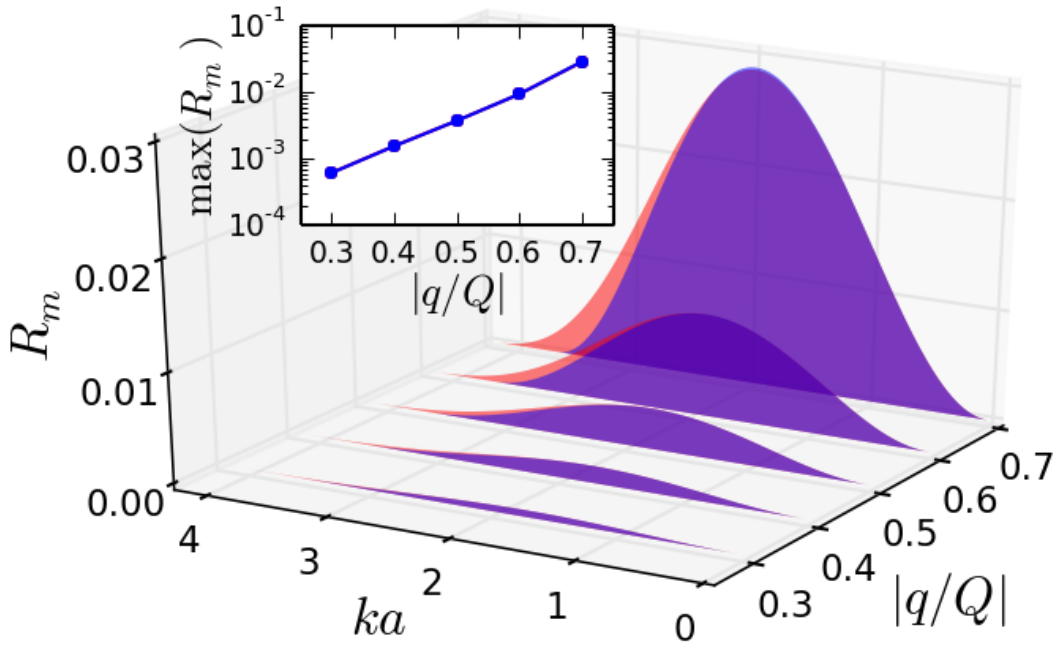
Mixed Polarization Ratio: Sim





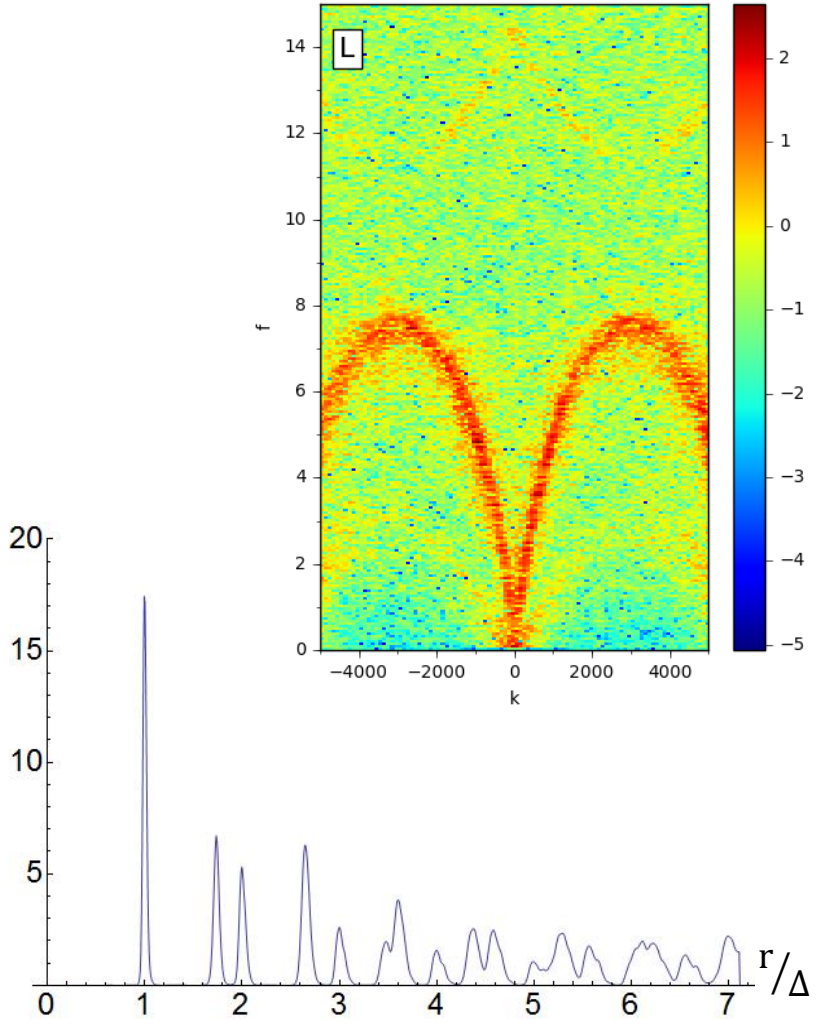


Mixed Polarization Ratio: Theory



Conclusions

- Increased diameter and number of particles in a crystal
  - Electrode diameter 4x
  - Particle number 3.5x
  - Crystal diameter 4x
- Low pressures reduce damping and allow more particle motion
  - 0.10 Pa for LC
  - 0.1 s^{-1} damping rate
- High particle and wake charge
- Flat across the width of the crystal
- Mixed polarization between vertical and longitudinal modes far from mode crossing



Thank You