Near-field
Optical Diffraction Radiation Measurements at CEBAF

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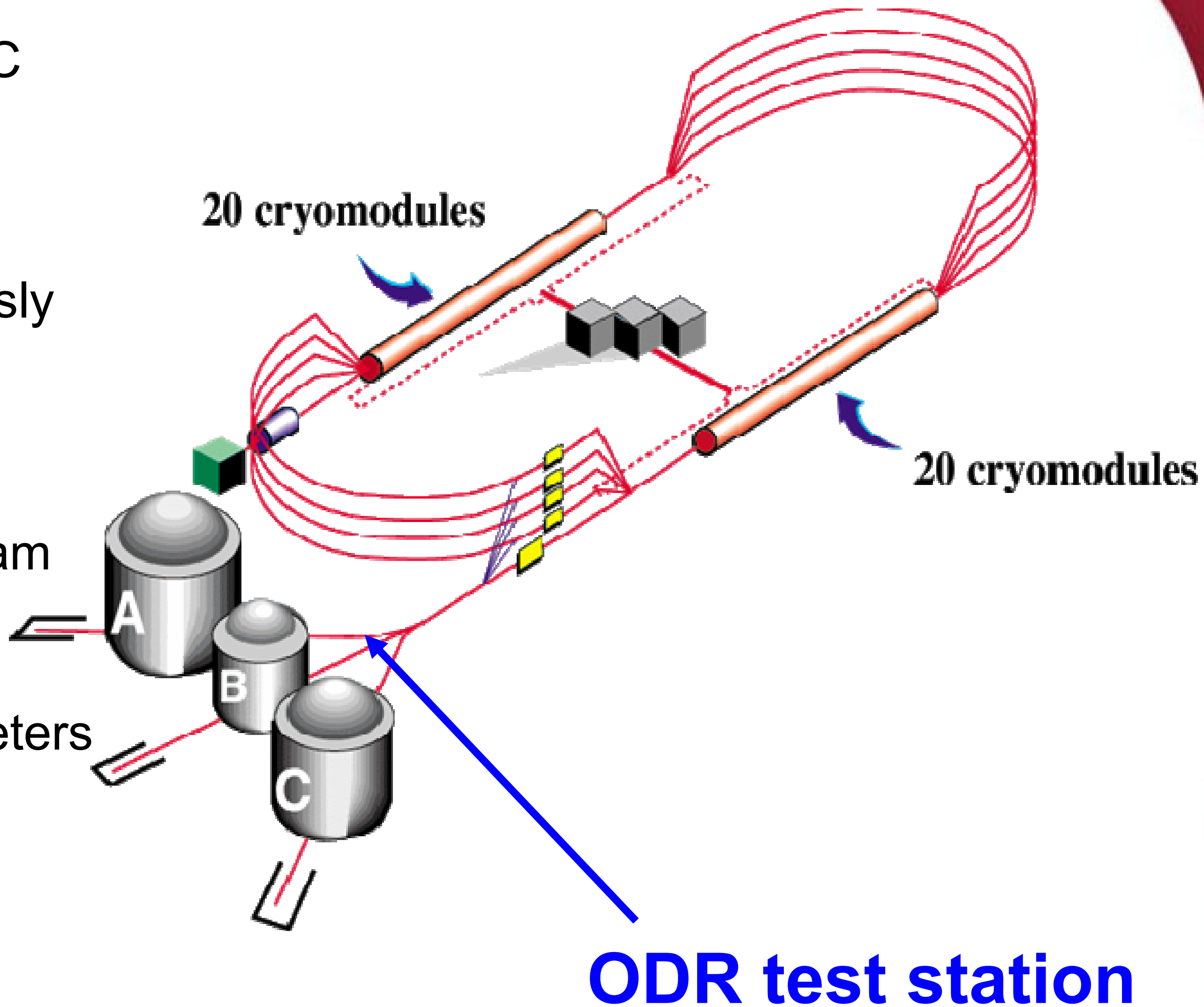
Outline

- CEBAF brief overview
- ODR basics (why would it work?)
- experimental setup
- experimental results vs. model
- conclusion

CEBAF

- multi-pass SRF LINAC
- up to 6 GeV – 100 μA
- 3 beams simultaneously
- $\varepsilon_g \approx 1$ nm (design)
- important to know beam size on NP targets
- monitor Twiss parameters online with CW beam
- $\frac{100\mu A}{60Hz} = 1666.667\ nC$



A. Lumpkin et al., FEASIBILITY OF NEAR-FIELD ODR IMAGING OF MULTI-GEV ELECTRON BEAMS AT CEBAF, PAC07

ODR basics

amplitude of a Fourier component of transversal Coulomb field of an electron

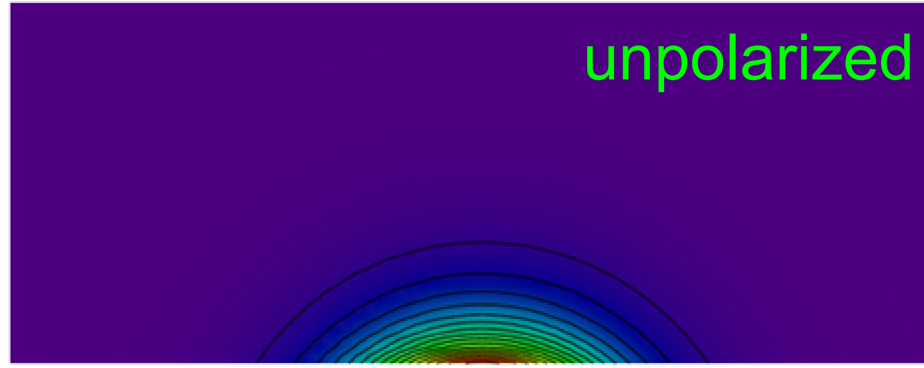
$$E_{r\omega} = \frac{q_0 \cdot \alpha}{\pi \cdot v} K_1(\alpha \cdot r) \qquad \alpha = \frac{2 \cdot \pi}{\lambda \cdot \gamma \cdot \beta}$$

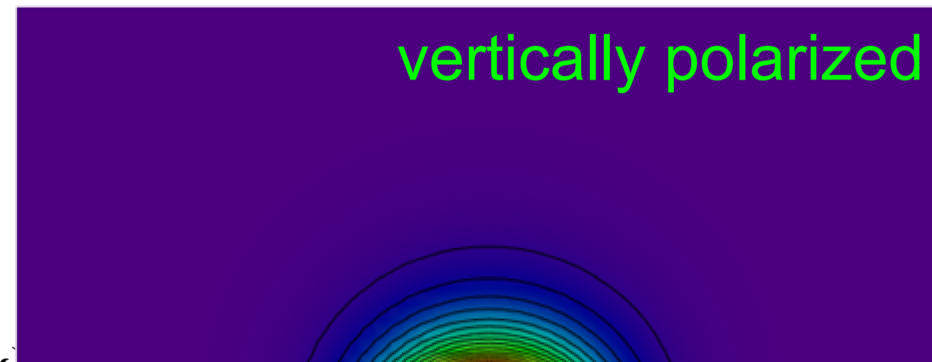
$f_b(x,y)$ - transverse beam distribution

intensity of the ODR from the beam Is 2D convolution of the f_b and $E_{r\omega}^2$

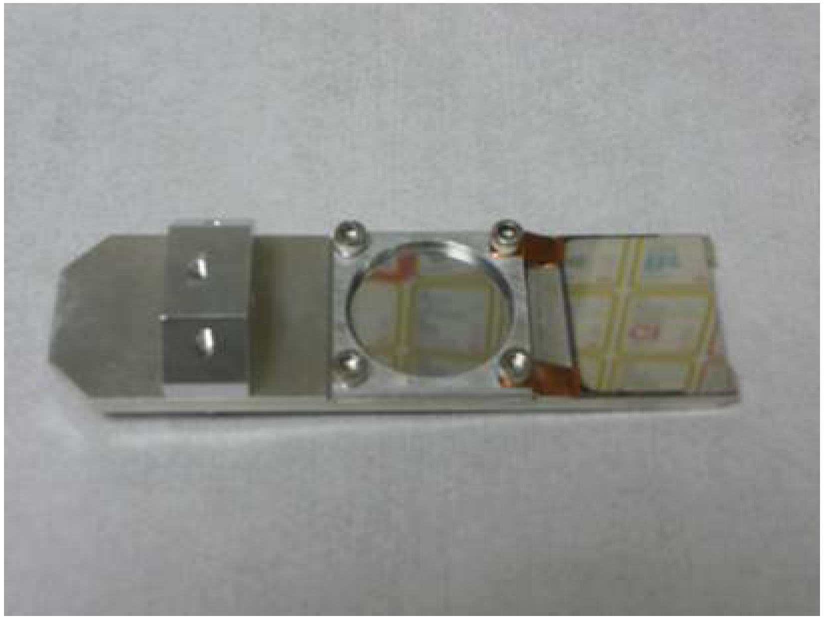
$$I_{beam} = \frac{1}{8\pi} \iint_{beam} f_b(\xi,\psi) \cdot [E_{r\omega}(\gamma,\lambda,x-\xi,y-\psi)]^2 \cdot d\xi \cdot d\psi$$

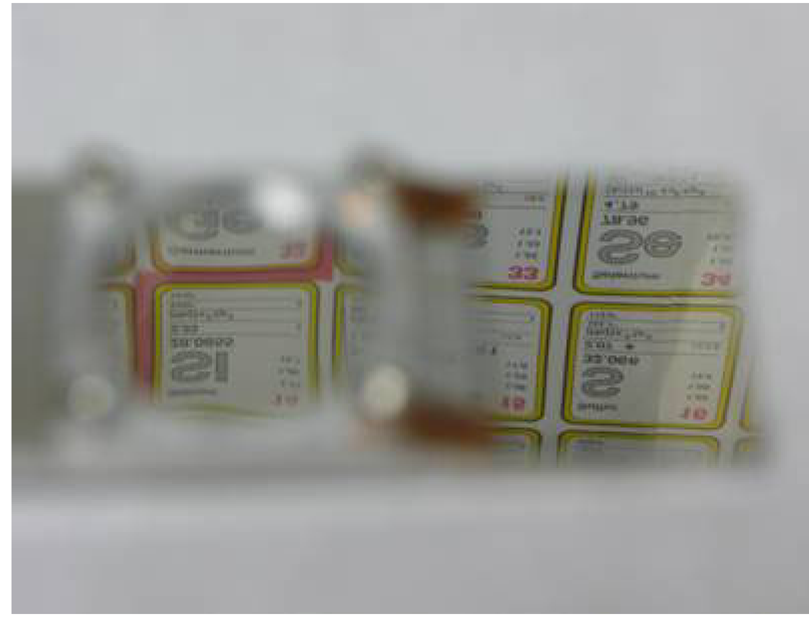
Example assuming
4.597 GeV;
σ_x=215 μm; σ_y=110 μm;
λ=550 nm; h=1.1 mm

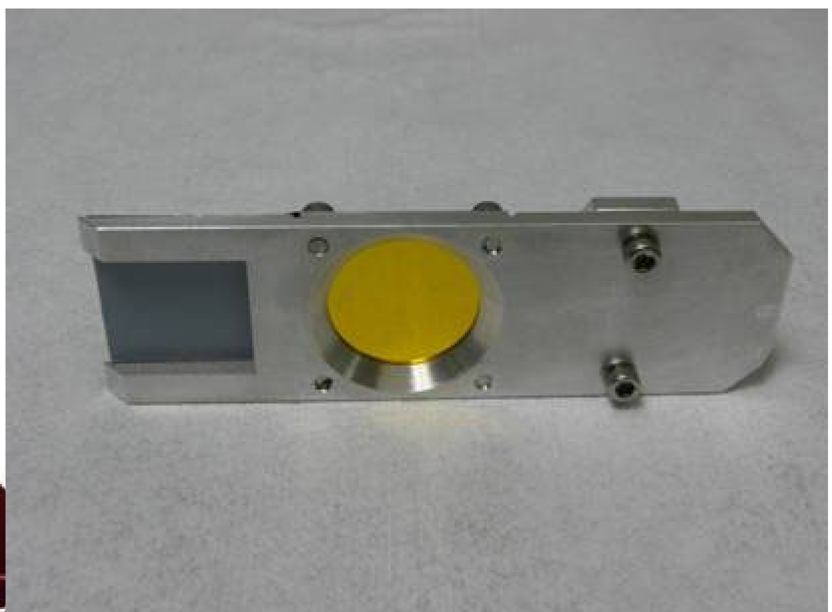




ODR-OTR radiator





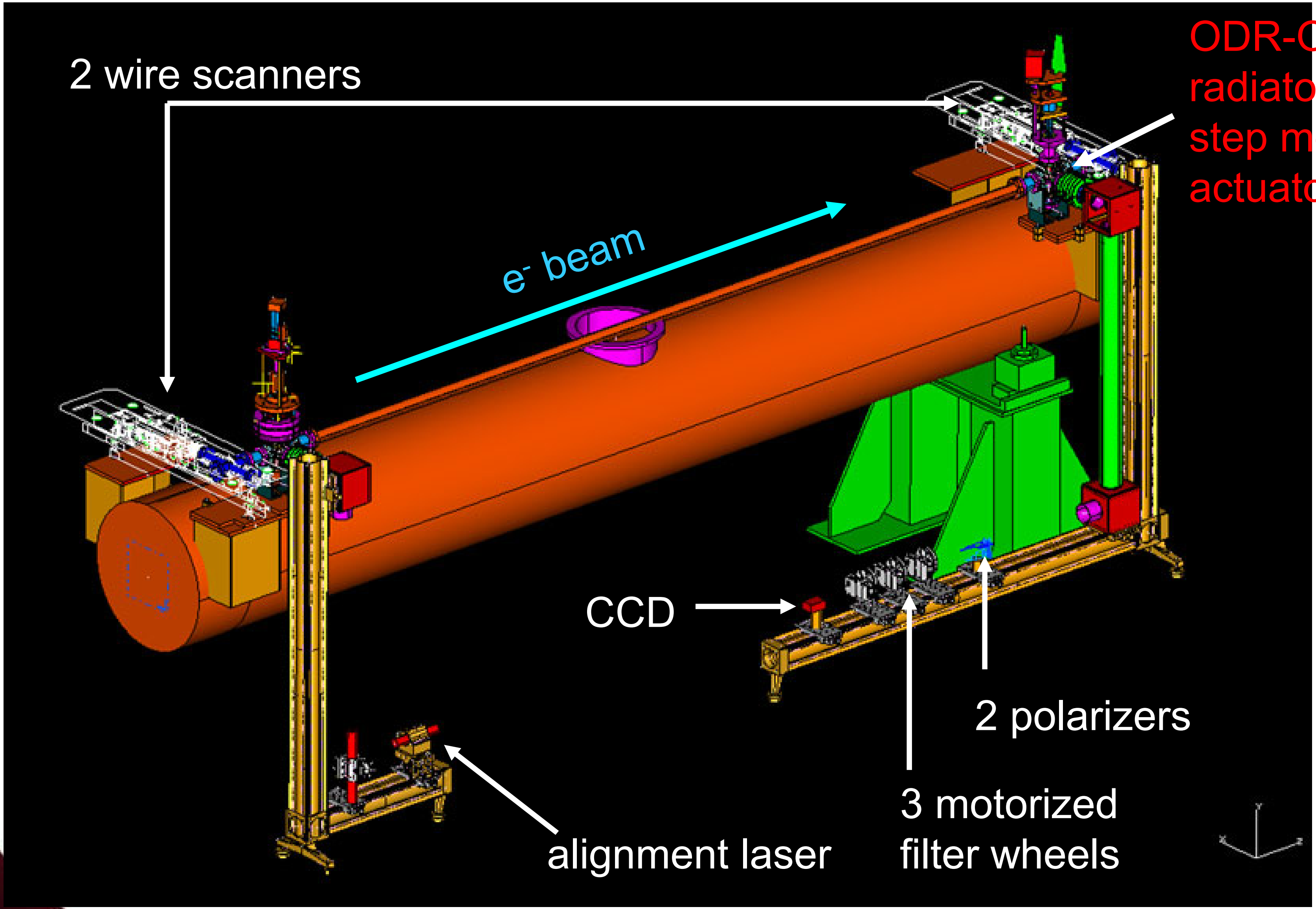


ODR radiator – 300 μm aluminized Si wafer 28 mm×20 mm

OTR radiator – 6 μm aluminized Kapton, stretched, ∅ 20 mm

both are optical quality surface (mirror like for optical wavelength)

ODR setup schematic



ODR setup in tunnel

ODR setup summary

- ODR radiator: aluminized 300 μm Si wafer
- OTR radiator: aluminized 6 μm stretched Kapton

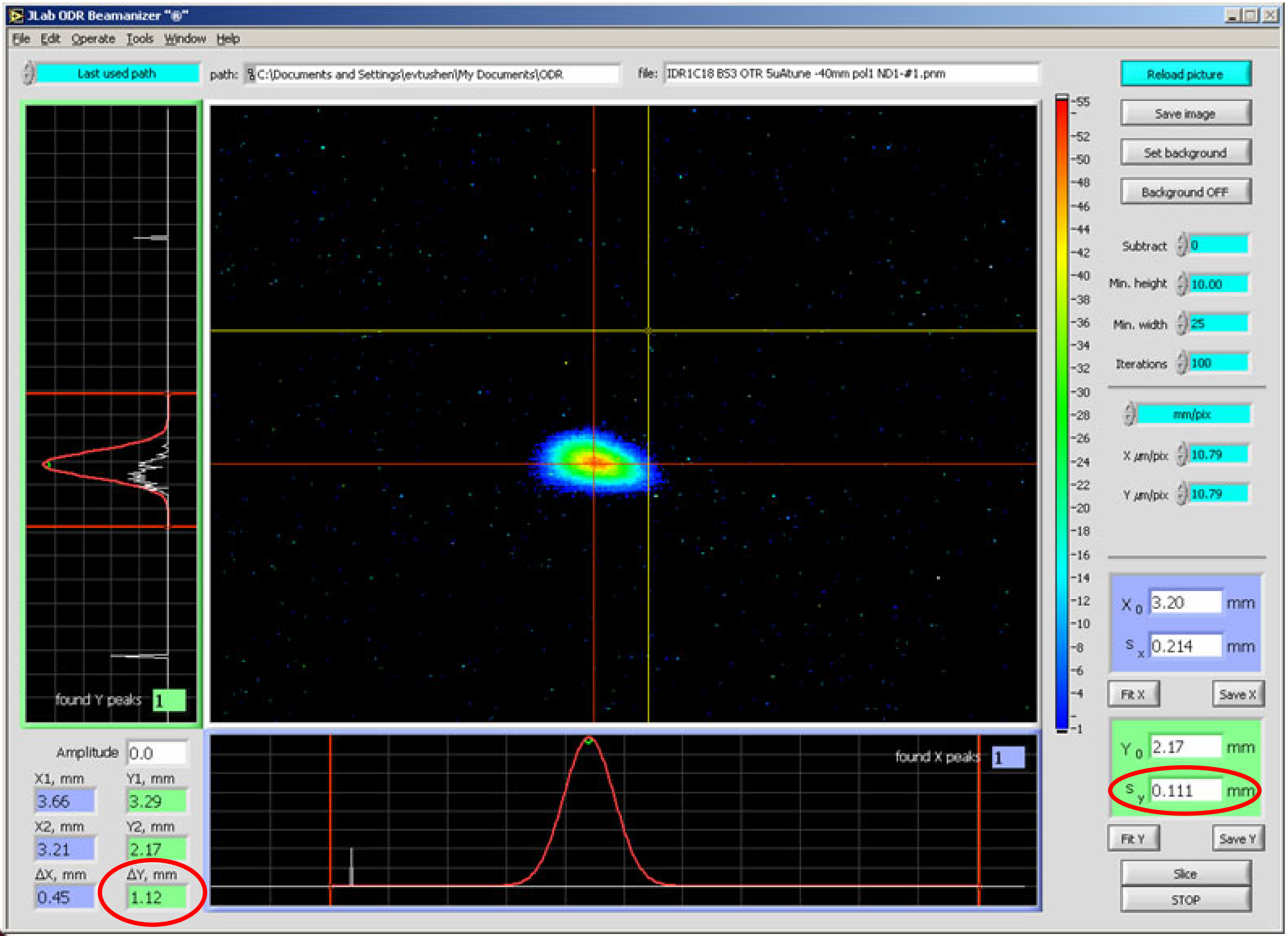
- imaging is done with two 2`` achromatic lenses
- diffraction limit of optics is ~ 10 μm

- band pass filters: 450×10 nm, 550×10nm, 650×10nm, 750×10nm, 750×40nm, 500nm LP, 500nm SP
- set of ND filters
- insertable polarizers (vertical and horizontal)

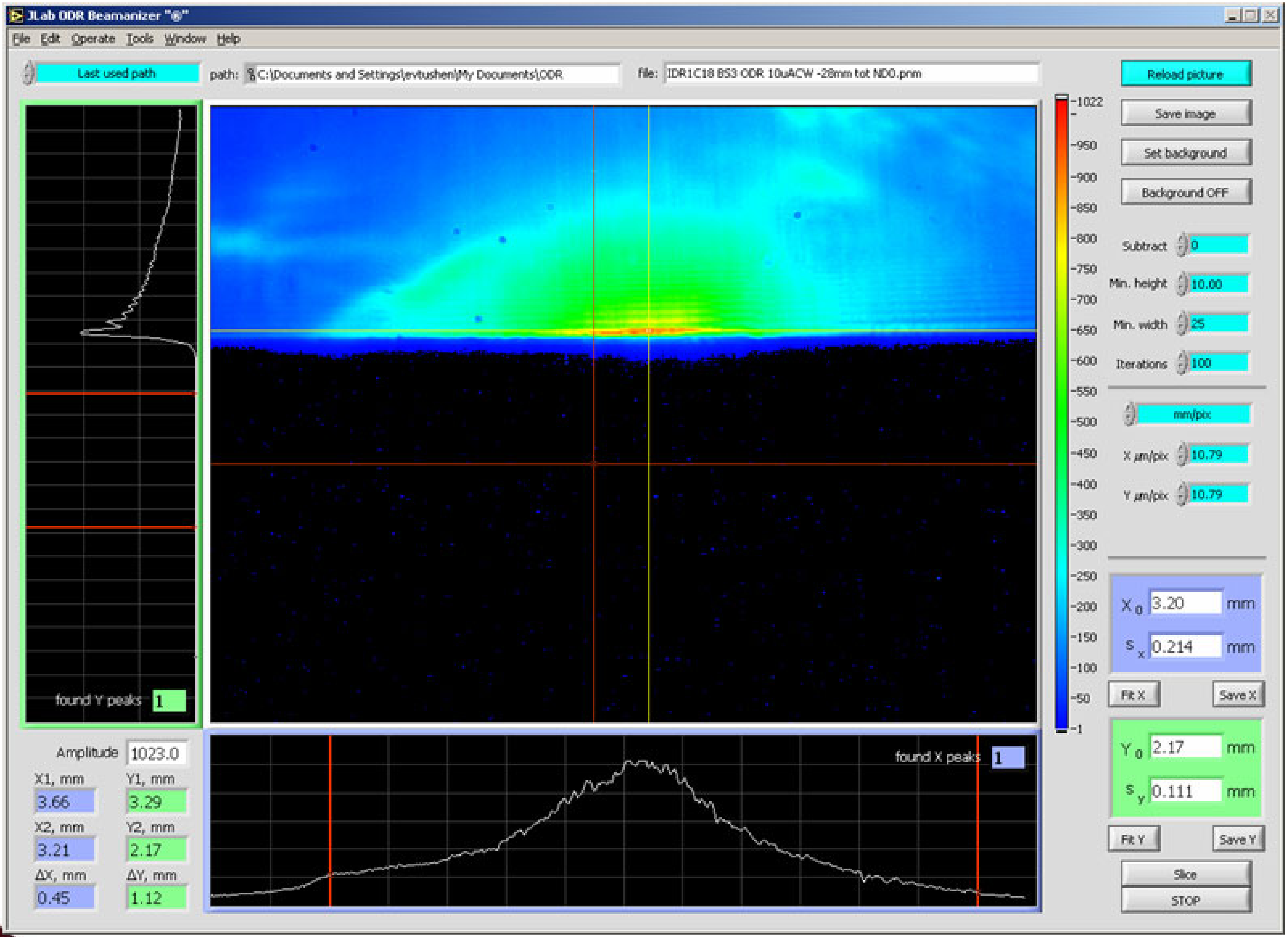
- a simple CCD camera (JAI-A60) 60 dB SNR
- frame grabber: 10-bit (National Instruments)

- alignment laser (set within 100 μrad to the beam)

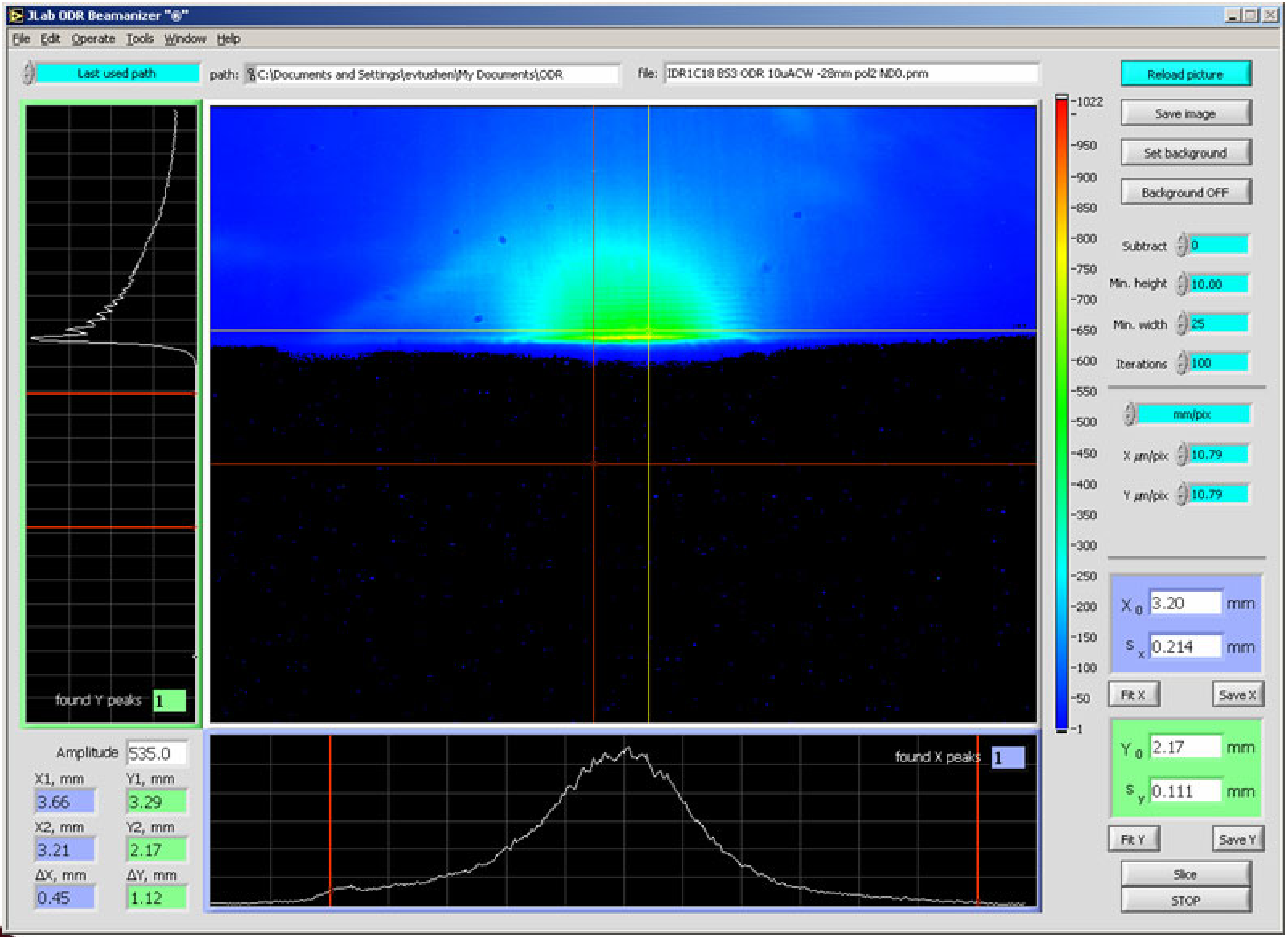
5μA tune beam; OTR



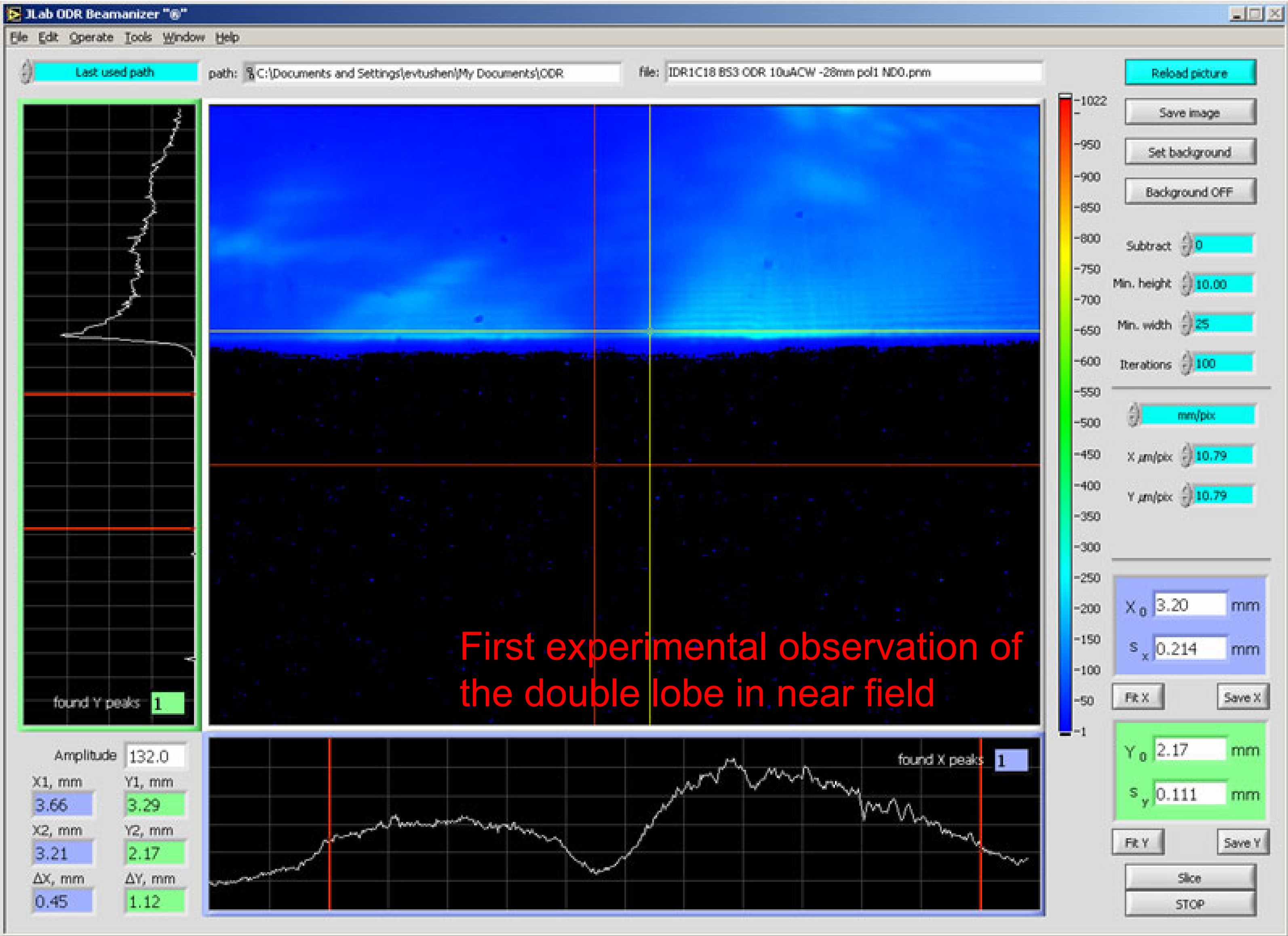
10μA CW beam; ODR unpolarized



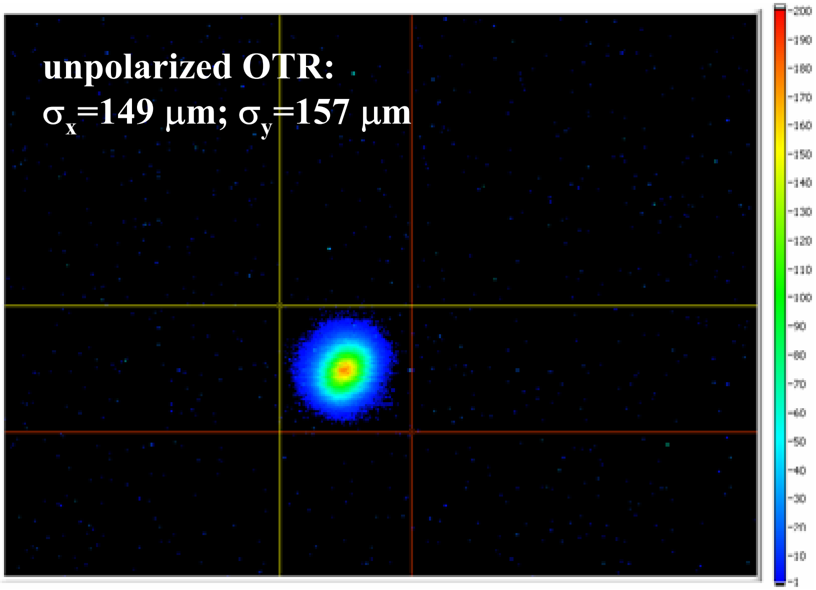
10μA CW beam; ODR V. polarized

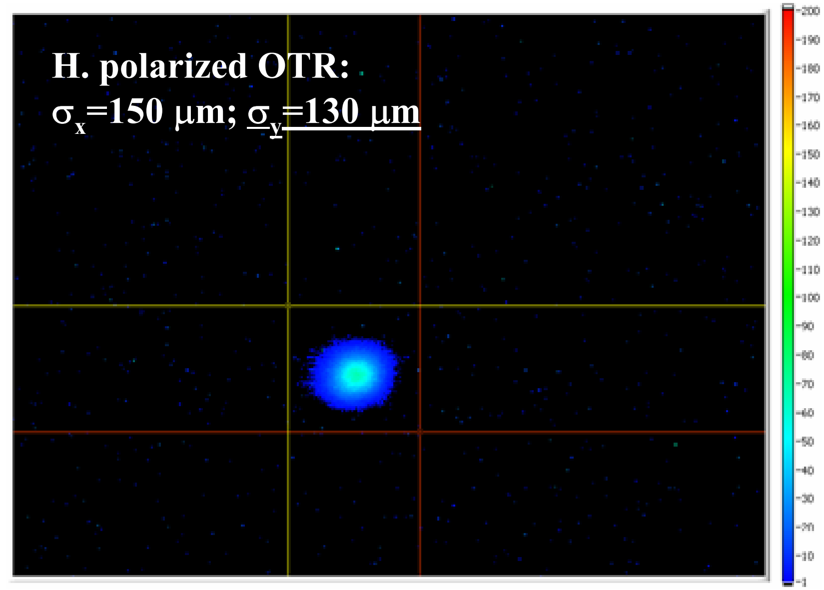


10μA CW beam; ODR H. polarized



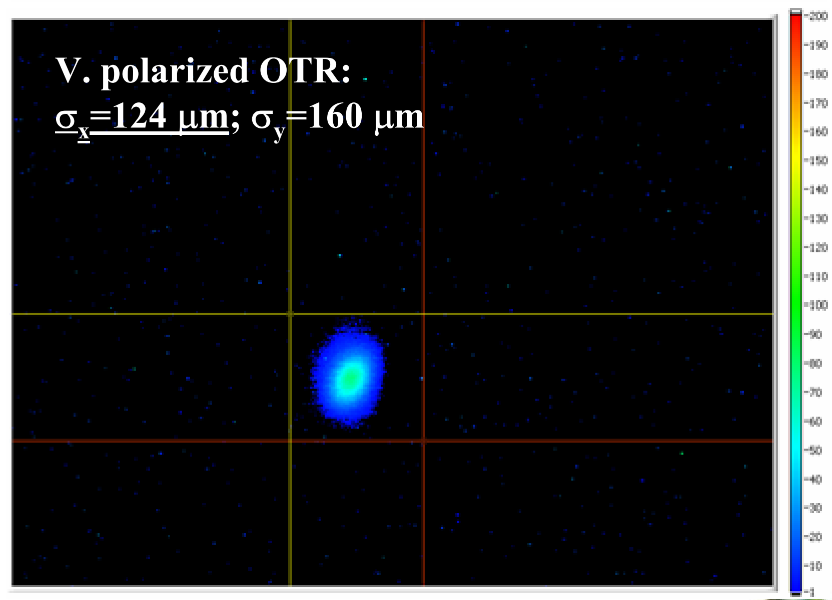
OTR on the ODR radiator (tune beam)



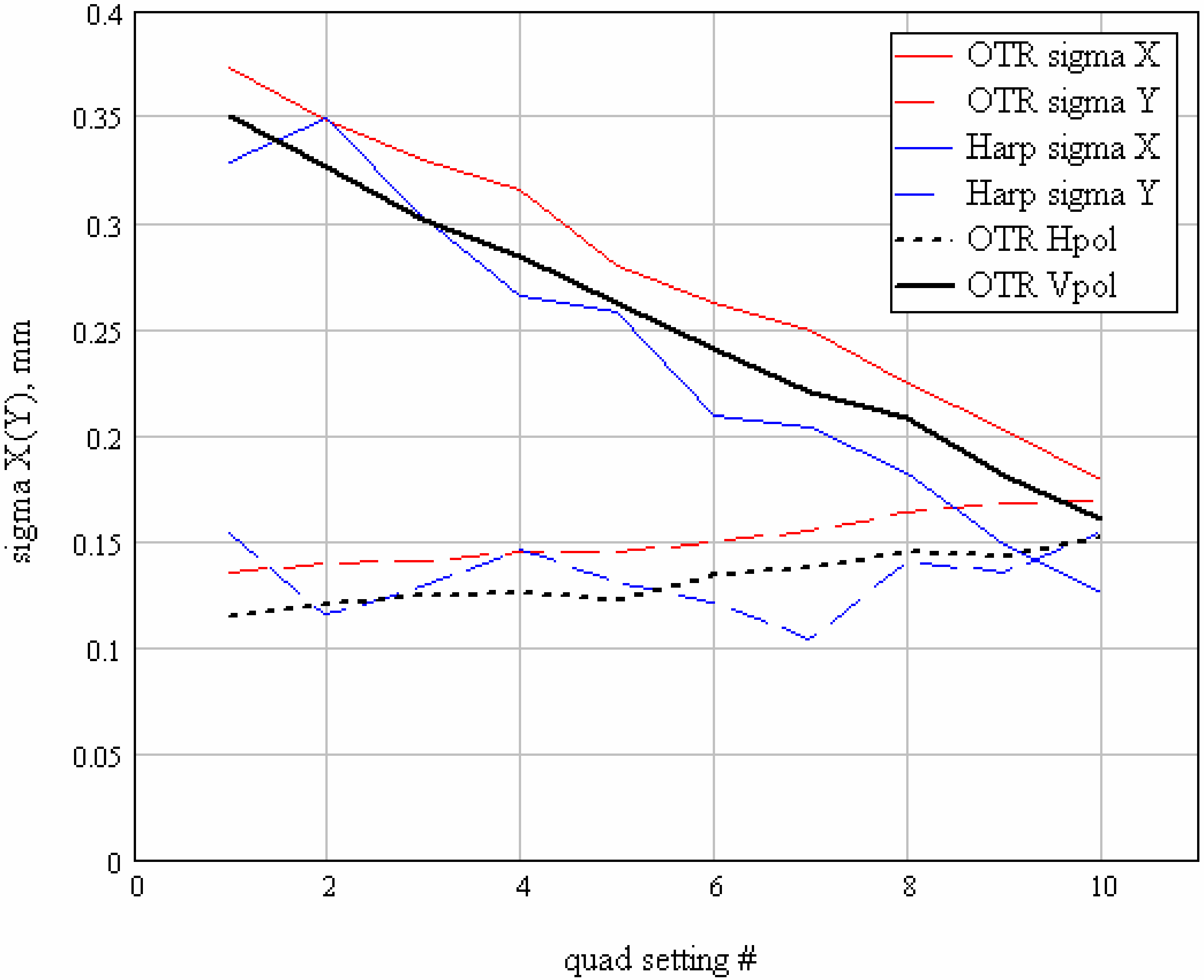


When measuring ODR pattern size vs. beam size, OTR was used to determine the actual beam size.

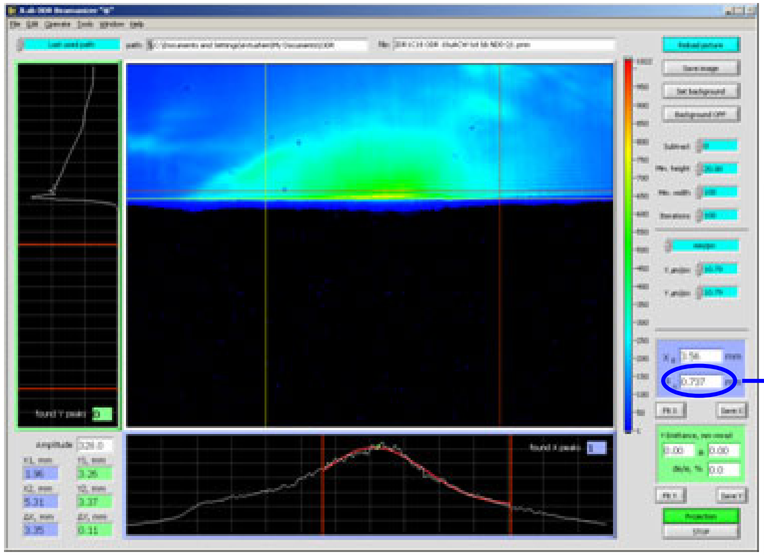
For our beam parameters (~150 μm) using a polarizer reduces makes 20% difference for measured beam size.

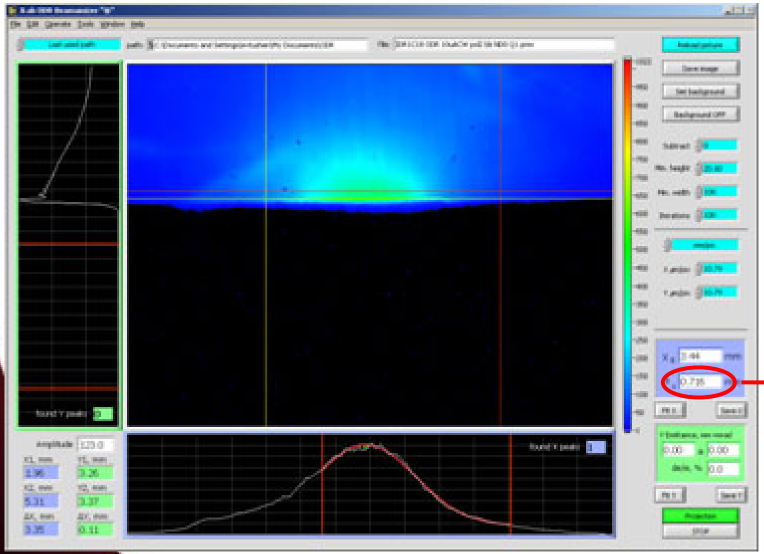


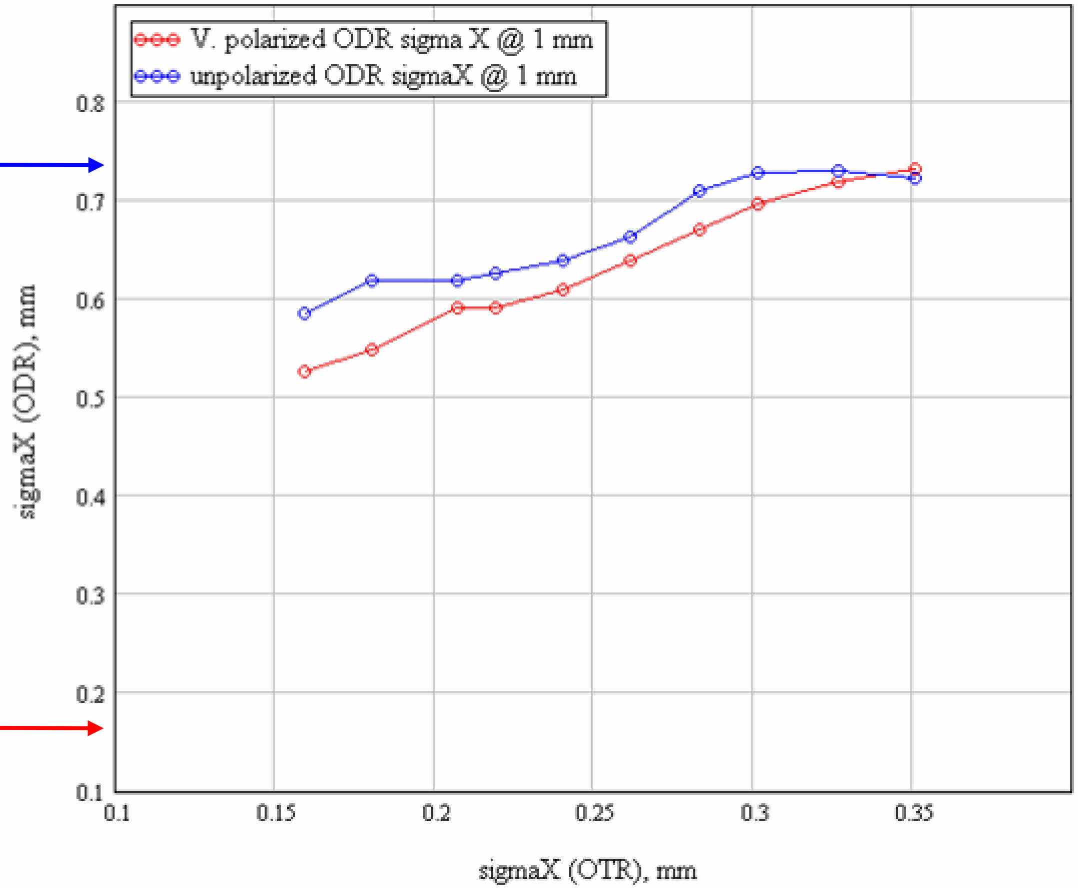
OTR vs. wire scanner



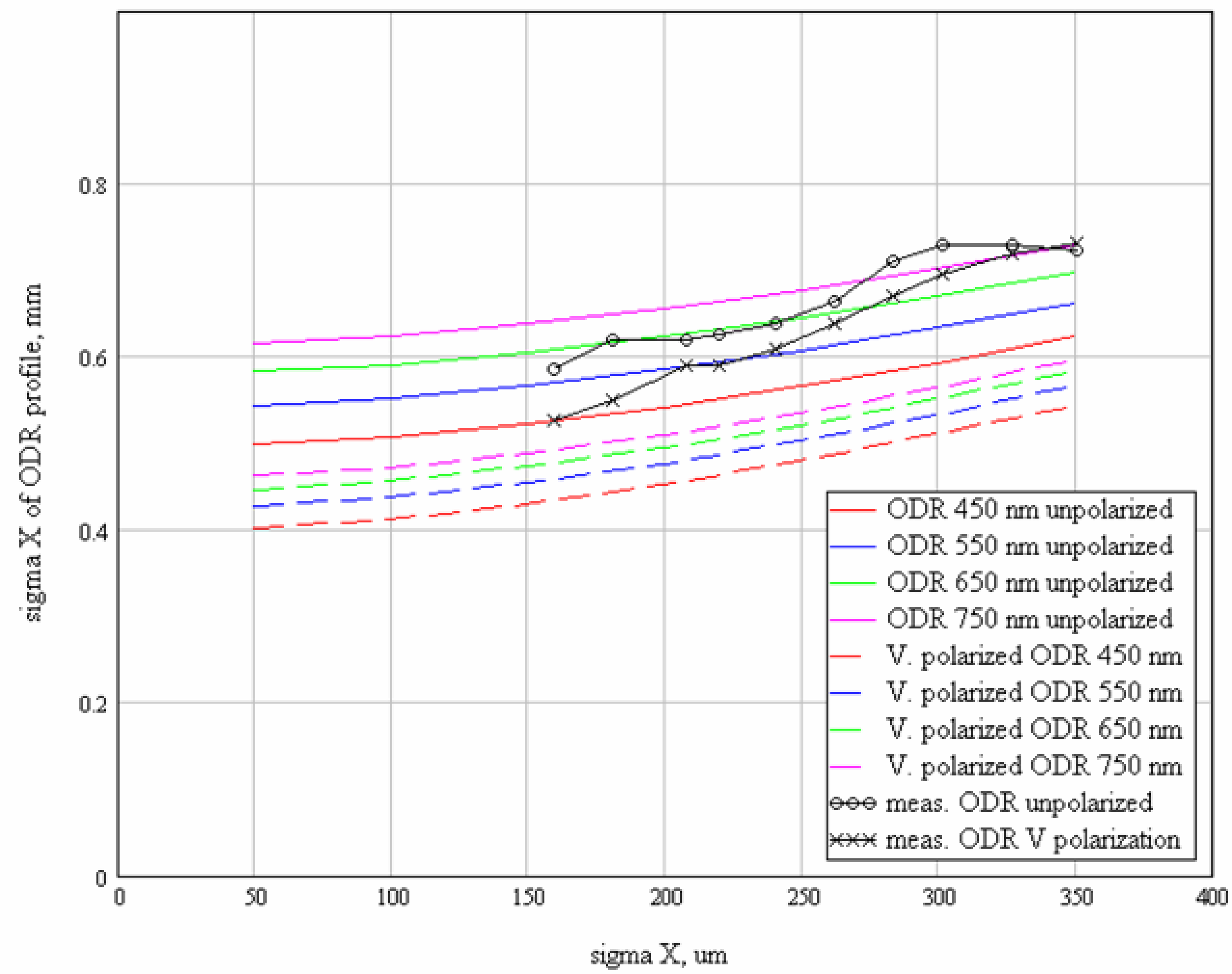
ODR distribution vs. beam size



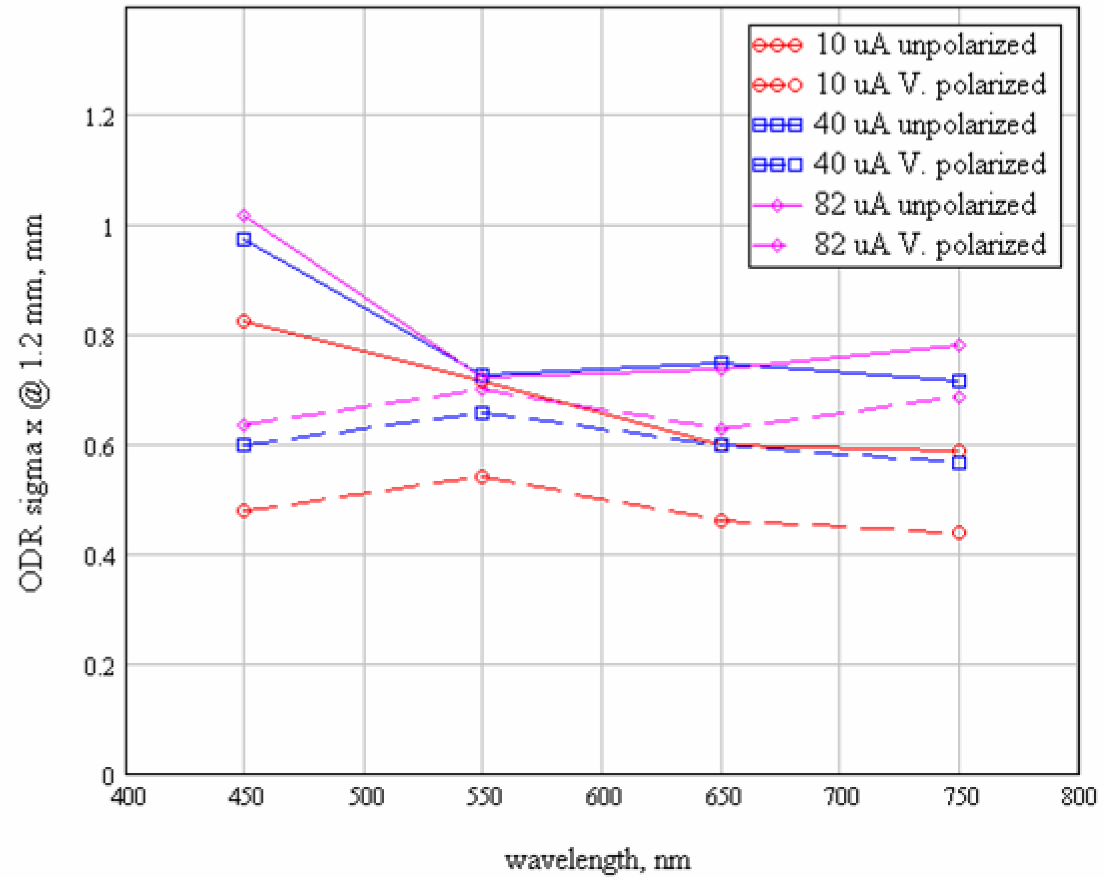




The experiment vs. model

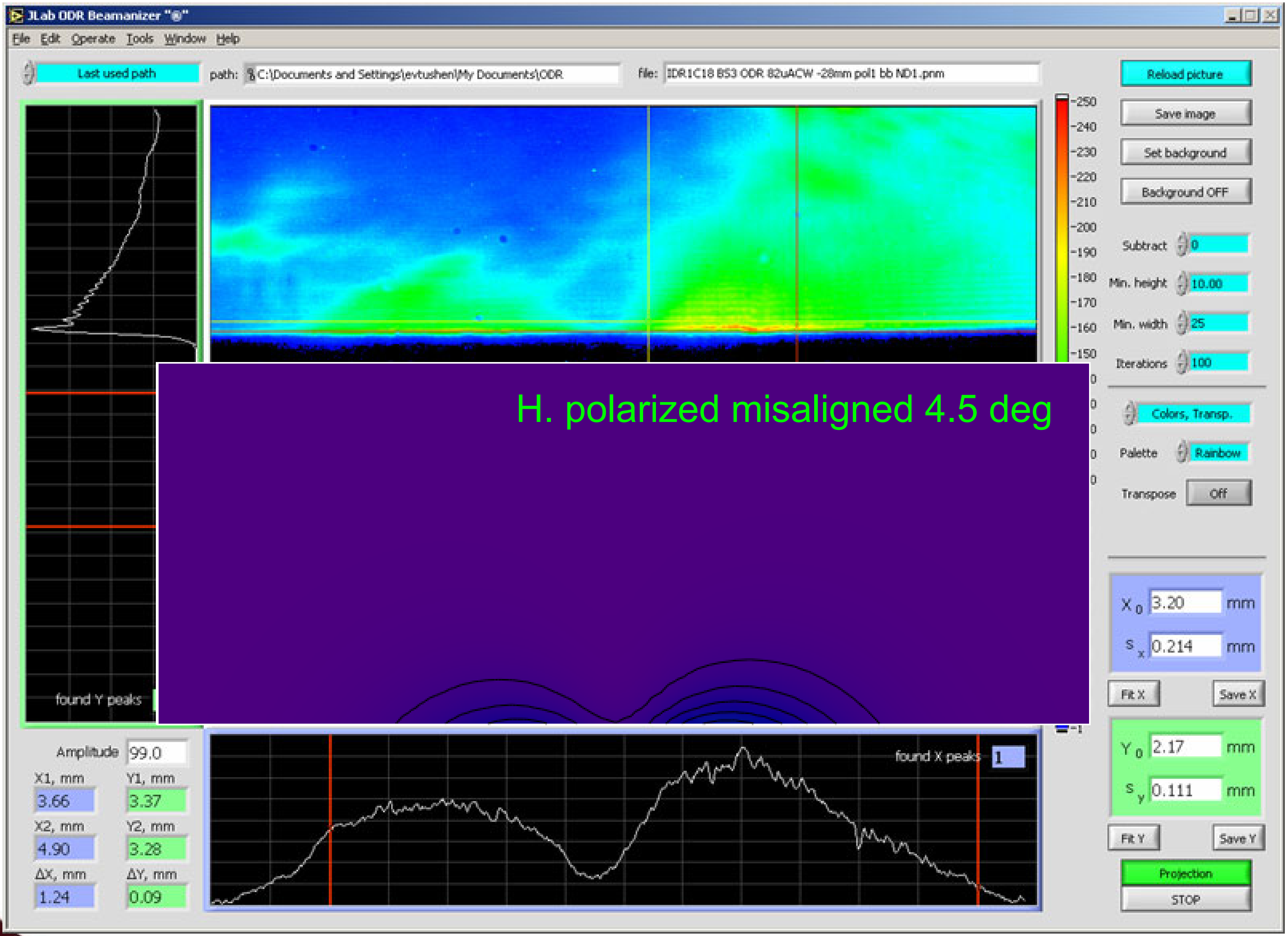


ODR (unpolarized and V. polarized) vs. λ and current

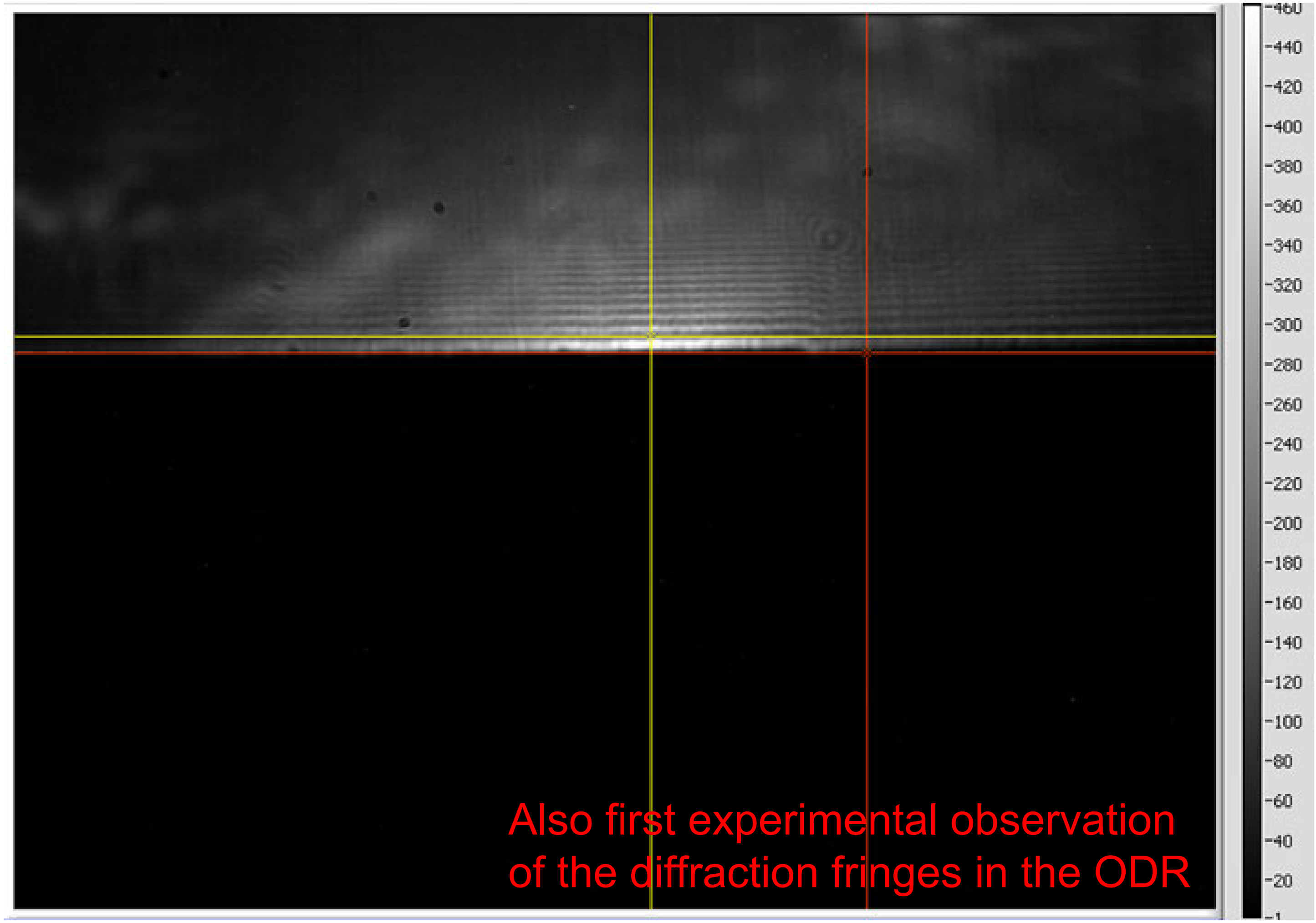


- the simple model predicts broader distribution for longer λ at any distance from the beam centroid; the data do not show it (?)
- the data suggest beam size change when going from 10 μA to 40 μA, but about the same beam size for 40 μA and 82 μA

H. polarized data ~60% asymmetry



Diffraction fringes



Does look a lot like a classical diffraction on a straight edge.

But that requires transversally coherent wave front. Why is it coherent?

Because the source size **($\lambda\gamma$) is much bigger than transverse beam size**.

Conclusion

- ODR measurements with CW beam up to 82 μA; no detectable beam loss; ~ 10$\times\sigma_y$ away from the beam, very high signal level
- demonstrated ~ linear ODR pattern (V. polarized) dependence on the σ_x in the range 150 μm – 350 μm
- for V. polarization data difference between the experiment and the model ~ 20 %
- strong and polarized background – make the data evaluation difficult (especially H. polarization)
- very clearly observed diffraction fringes – transversal coherence of the field (source size ($\lambda\gamma$) is much bigger than the beam $\sigma_{x(y)}$)
- first observation of double lobe for the H. polarization data, the observed asymmetry might due to misaligned polarizer
- have learned enough to refine the experimental setup
- probably need more sophisticated modeling to explain details of experimental observation