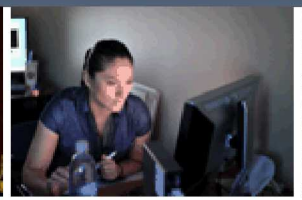
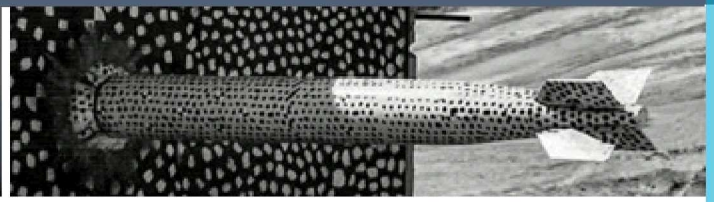
SAND2020-1382PE

Analysis of sample KAP crystals from INRAD





PRESENTED BY

Greg Dunham, October 22, 2019

Meeting with INRAD

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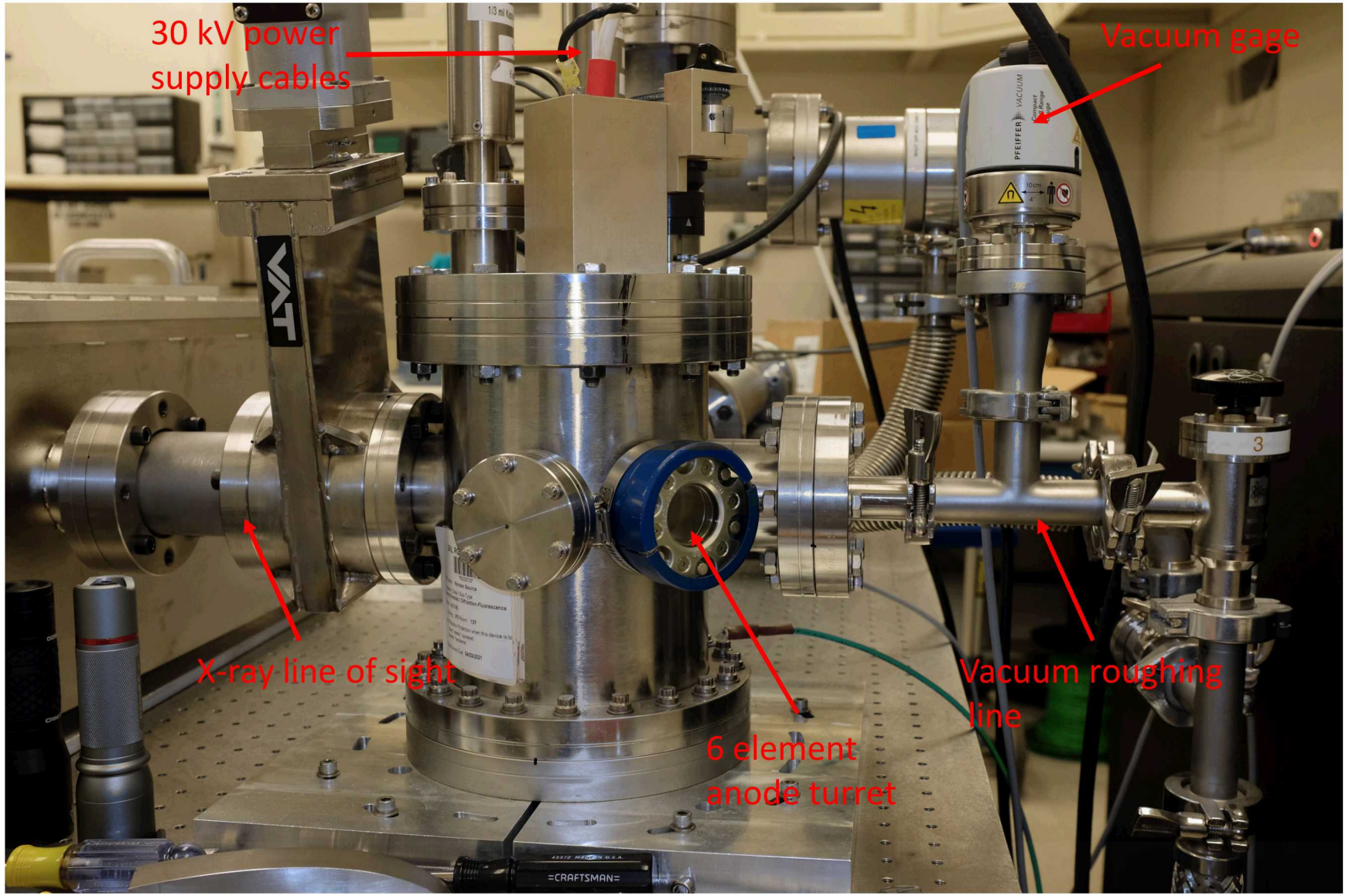
Outline

- Samples from INRAD
- Measurement technique for calibrations
- Images and data
  - Full images, detail image, and a vertical lineout
  - Horizontal lineout, line fitting and width measurements
  - Data table showing line widths and resolution
- Sample calibration dataset from nominal KAP crystals used for opacity measurements and other campaigns
- Summary

INRAD supplied KAP crystal samples

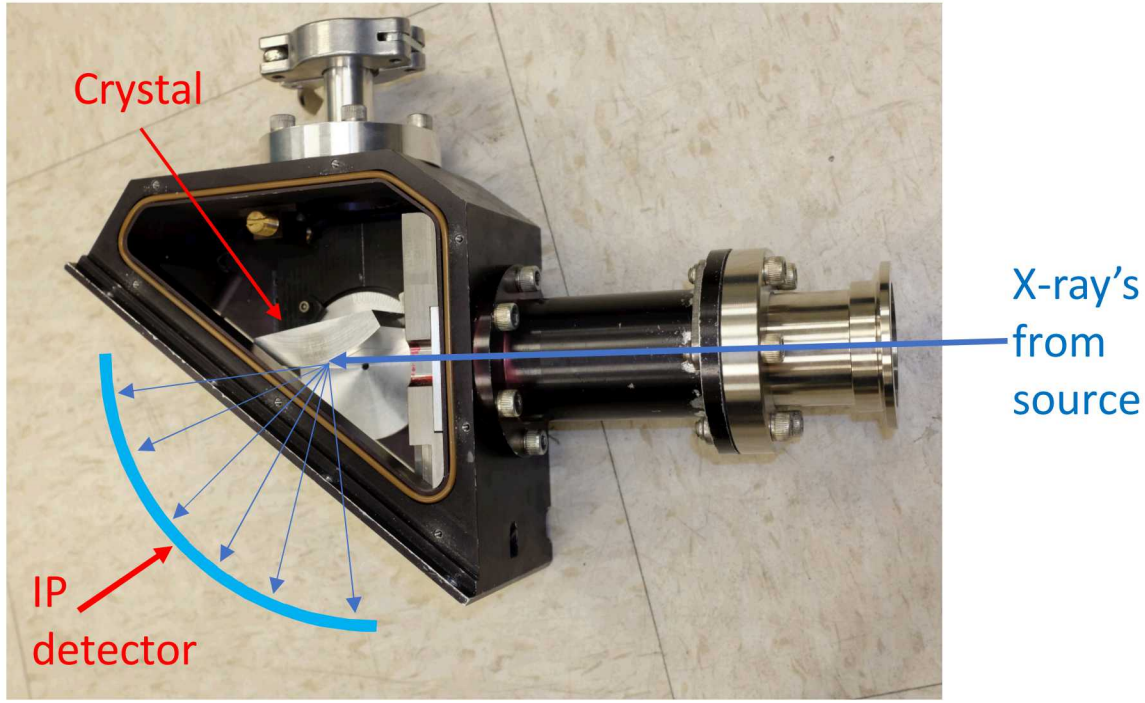
- Two 4” bend radius convex KAP crystals
  - 6482-4-1 & 6482-5-2
- Two 6” bend radius convex KAP crystals
  - 6482-6-1 & 6482-7-2
- Two mounting techniques were used with samples of each in both sizes.

Manson Source – 6 anode, 30 kV x-ray source

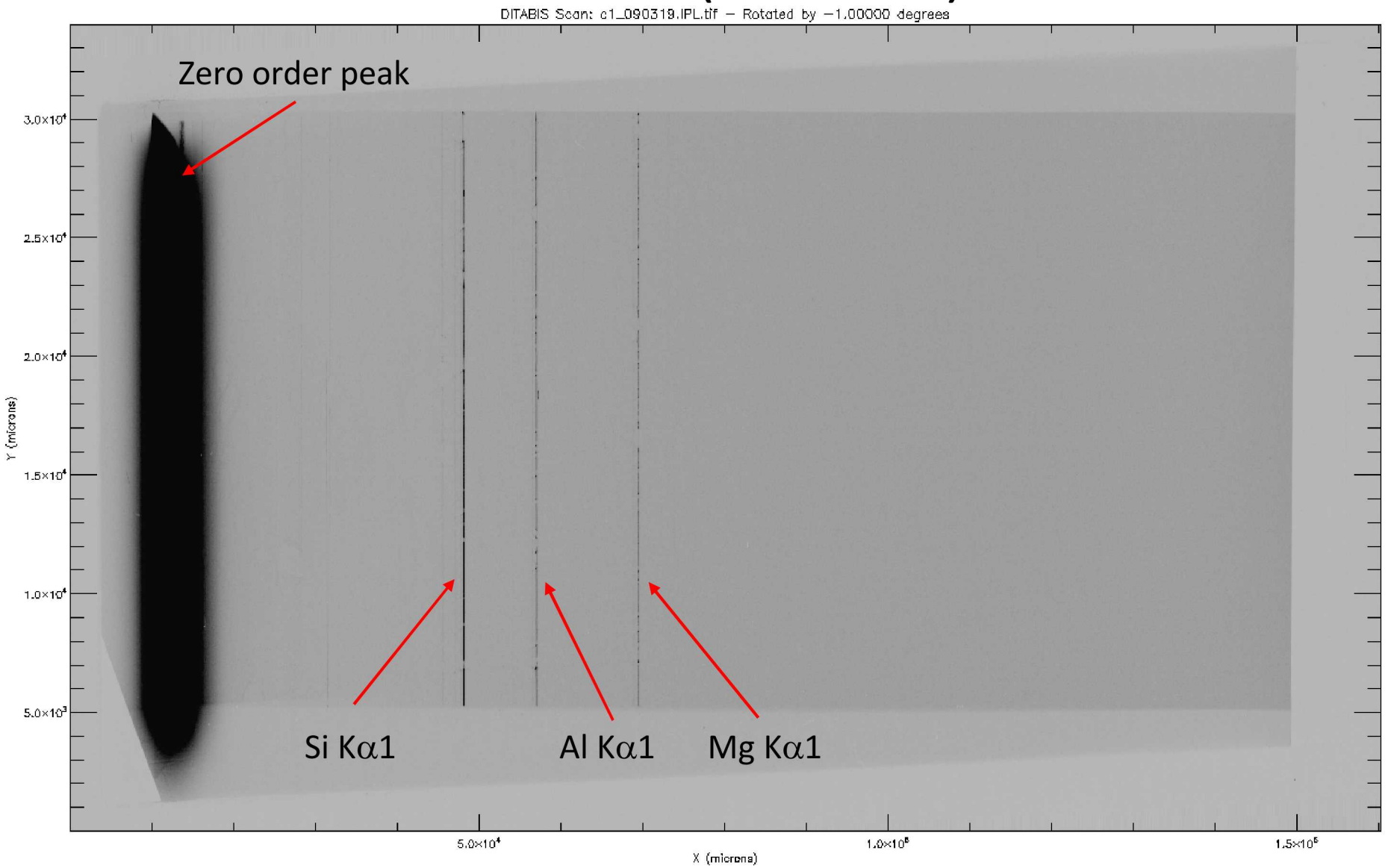


Calibration data obtained using x-rays from a Manson source.

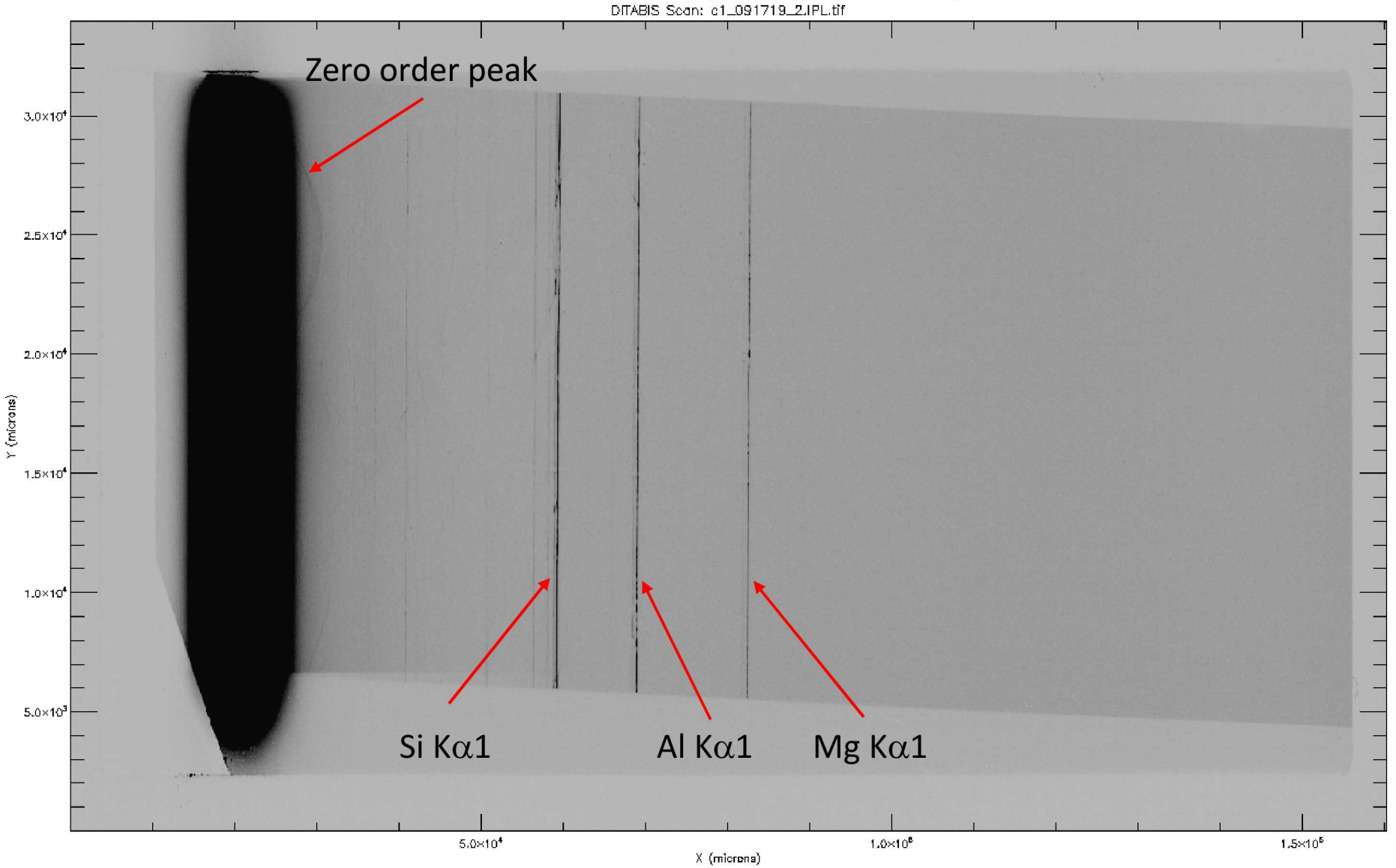
- Typical calibration setup
  - Mg, Al and Si anodes are excited to generate characteristic K-shell emission spectra at 1.254 keV, 1.487 keV, and 1.74 keV, respectively.
  - Crystals are installed in a time-integrating 1D-space resolving spectrometer (TIXTL).
  - Expose signal onto image plate (Fuji TR IP) for approximately 1 hour for each anode.
  - Scan data on an image plate scanner.
  - Analyze to determine qualitative and quantitative measurements of crystal quality and performance.



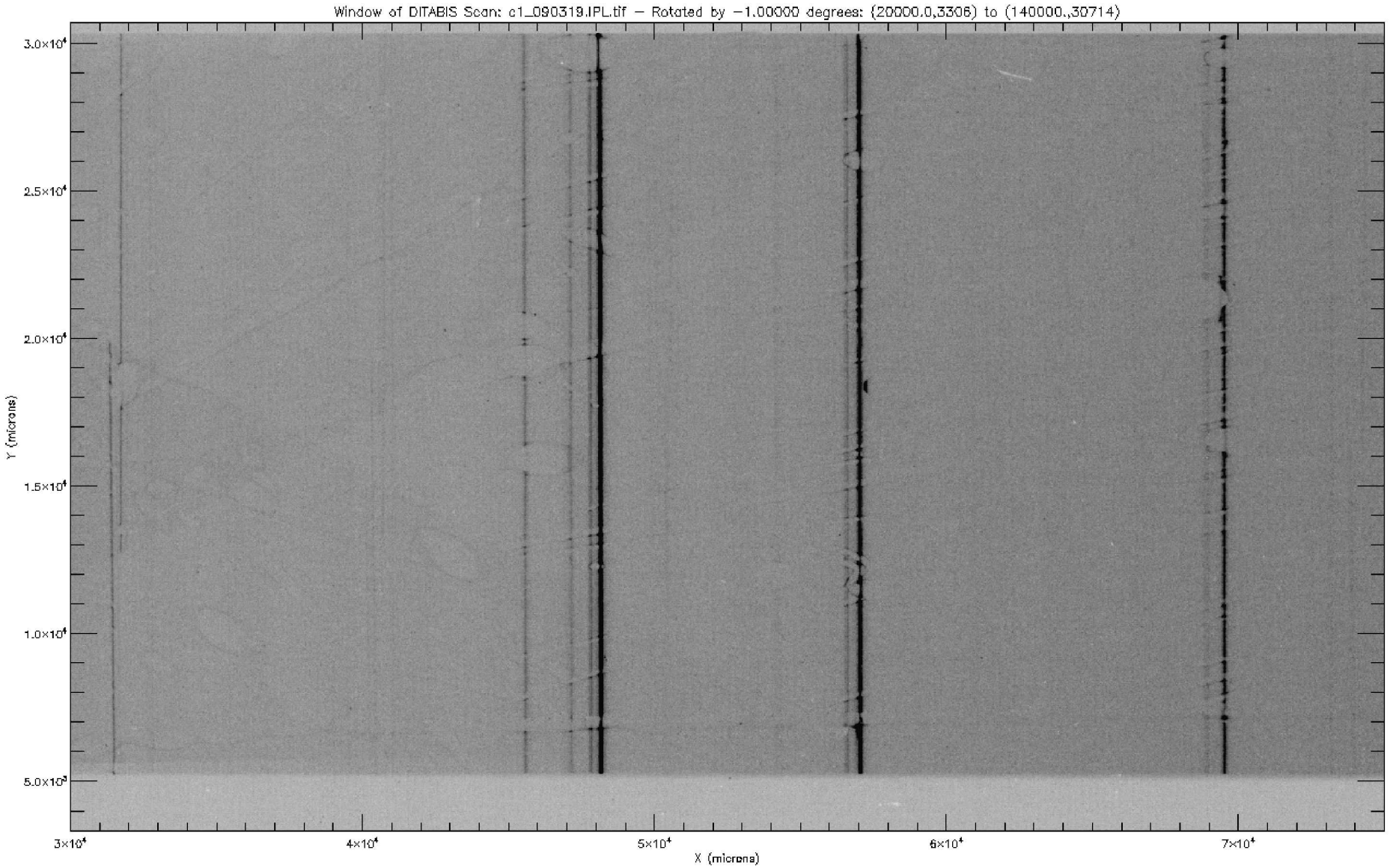
4” KAP 6482-4-1 (INRAD)



4” KAP 6482-5-2 (INRAD)

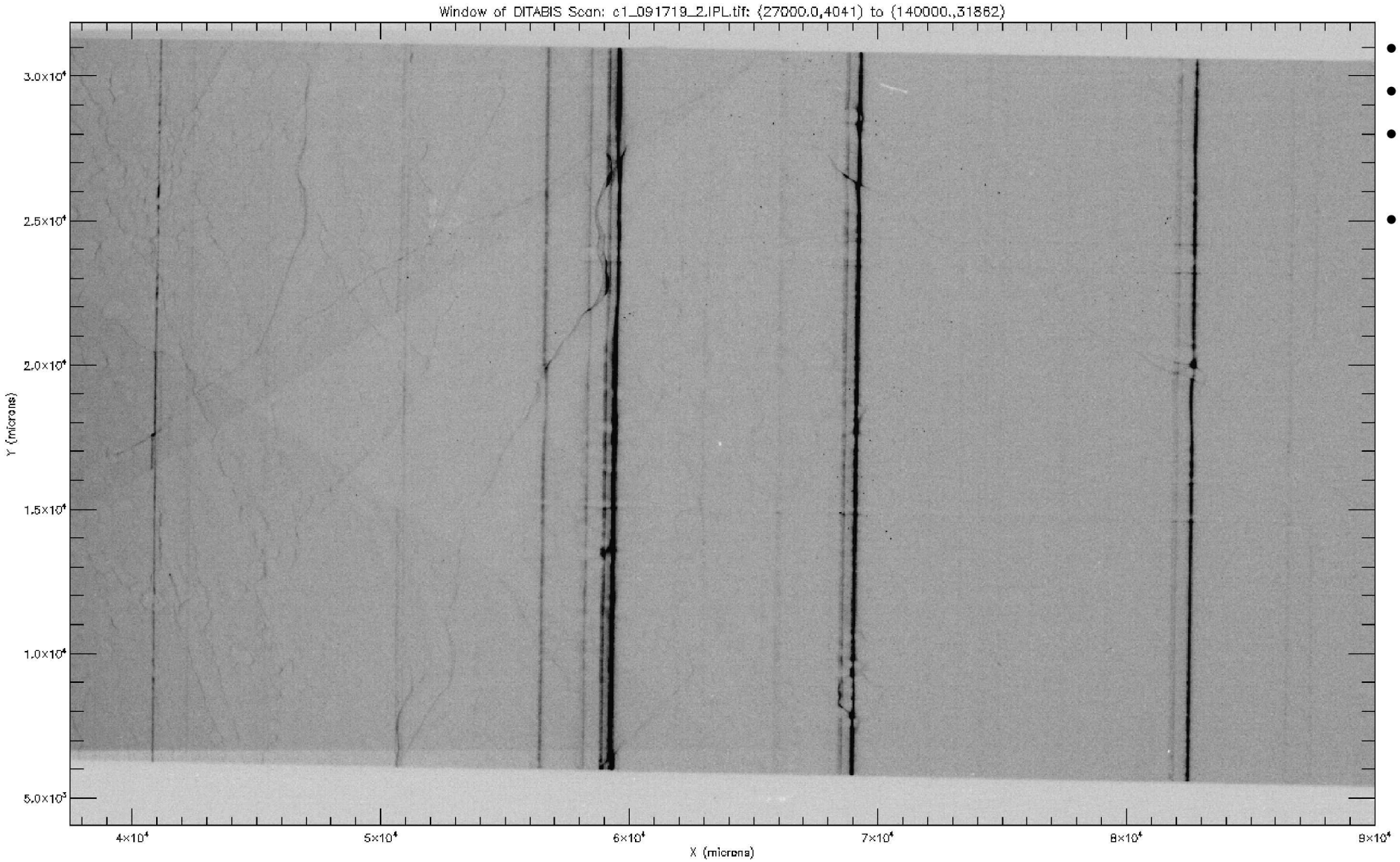


4” KAP 6482-4-1 Detail



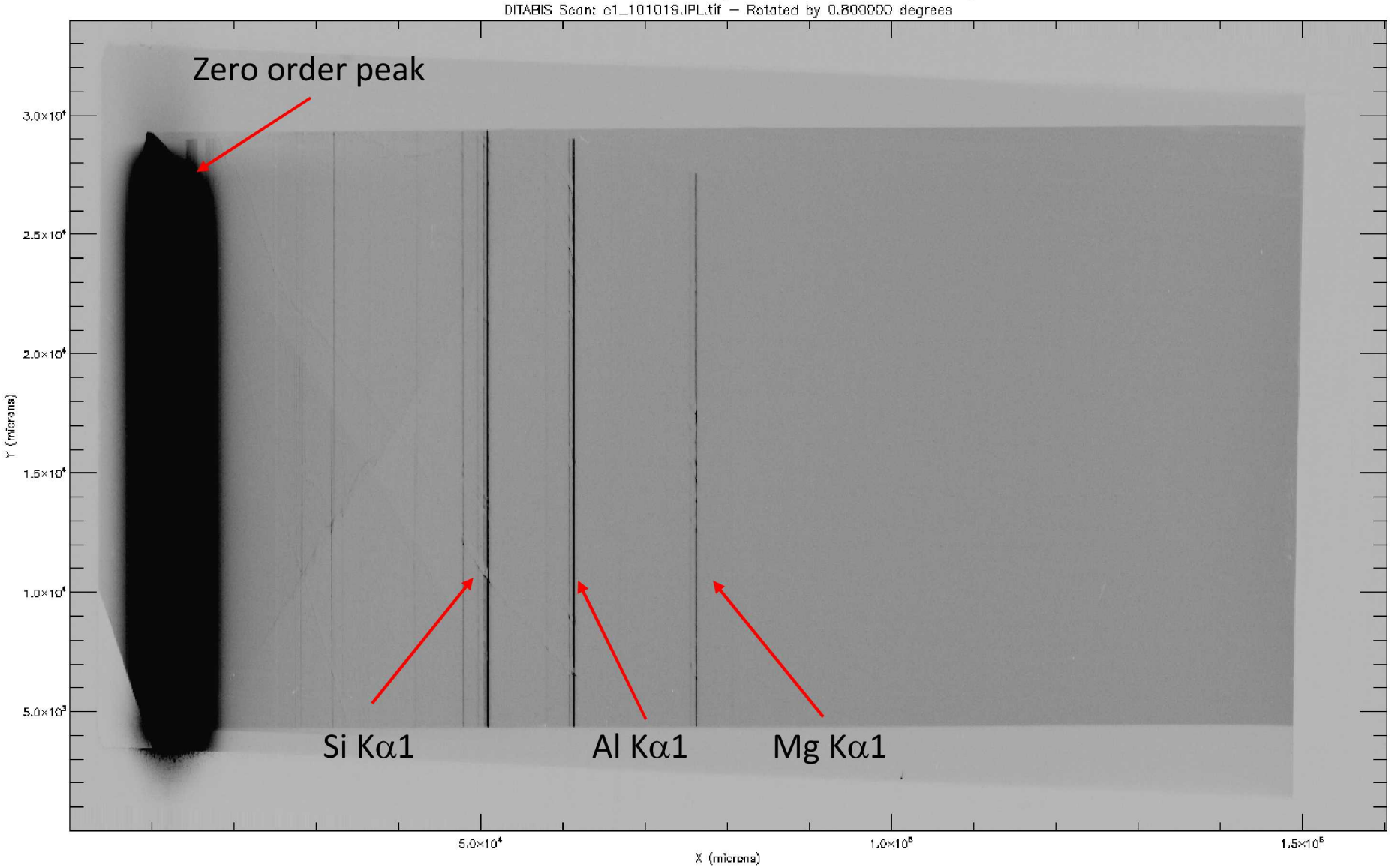
- Spectral lines are straight
- Bubbles are noticeable throughout image
- Higher order reflections create a cross pattern
- Lines are broken causing intensity variations
- Off-diagonal features extend across image

4” KAP 6482-5-2 Detail



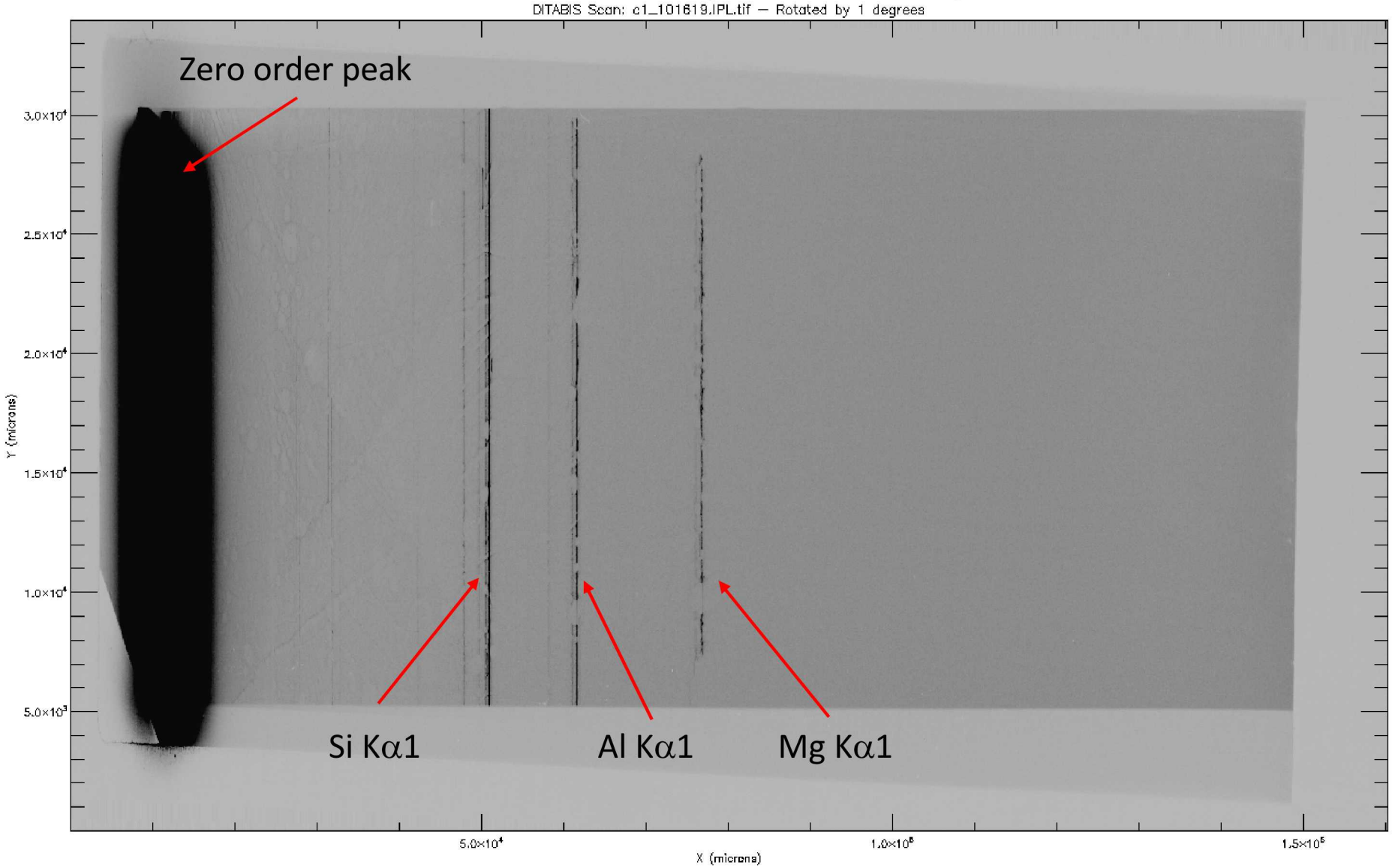
- Spectral lines not as straight
- Numerous wavy features
- Higher order reflections create a cross pattern
- Lines are broken causing intensity variations

6” KAP 6482-7-2 (INRAD)



- Qualitatively cleaner than 4” crystals
- Higher order reflections create a cross pattern
- Crystal planes appear to truncate at higher λ
- Spectral lines are straight

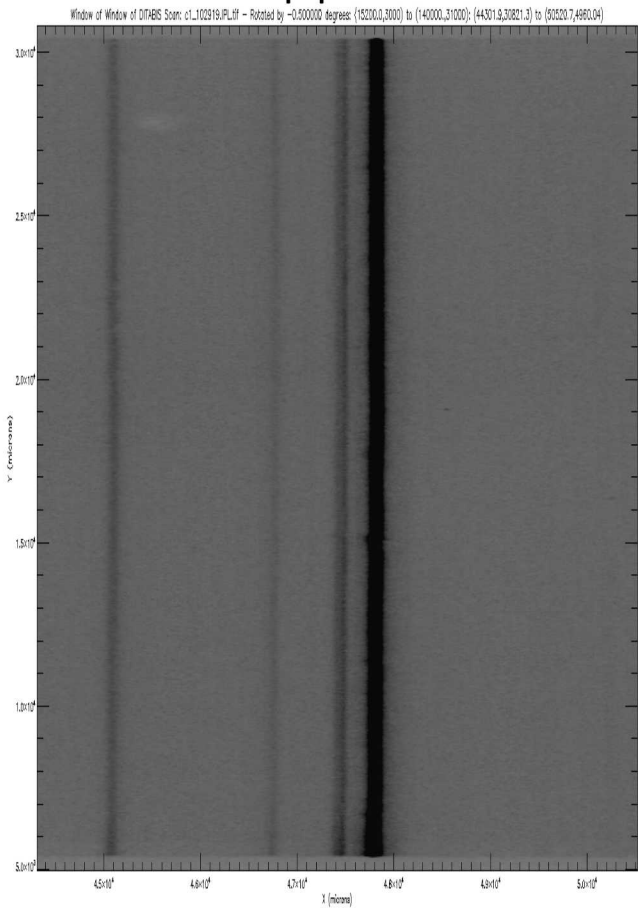
6” KAP 6482-6-1 (INRAD)



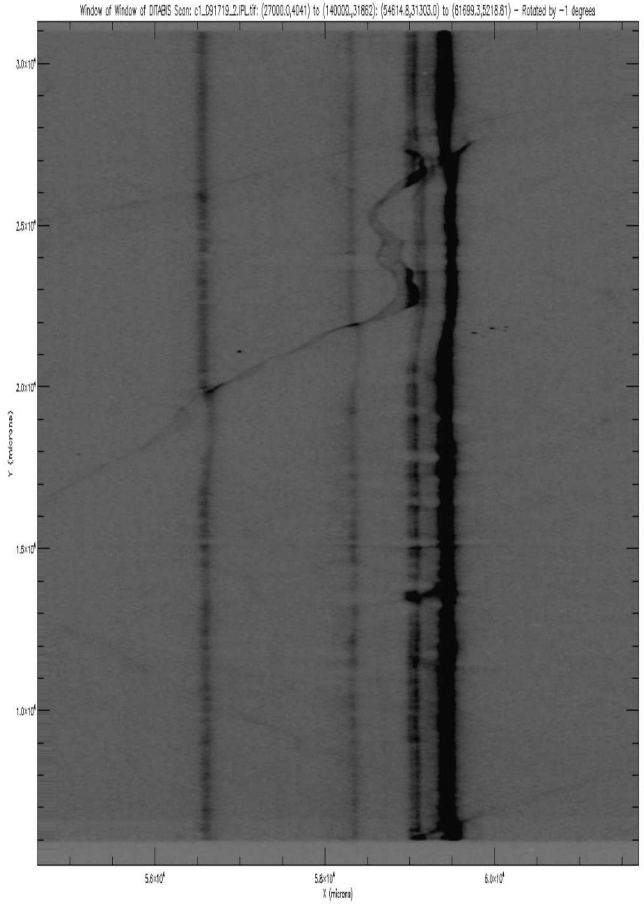
- Qualitatively similar level of imperfections
- Higher order reflections create a cross pattern
- More pronounced crystal planes truncation at higher λ
- Spectral lines are straight

Si Kα line detail

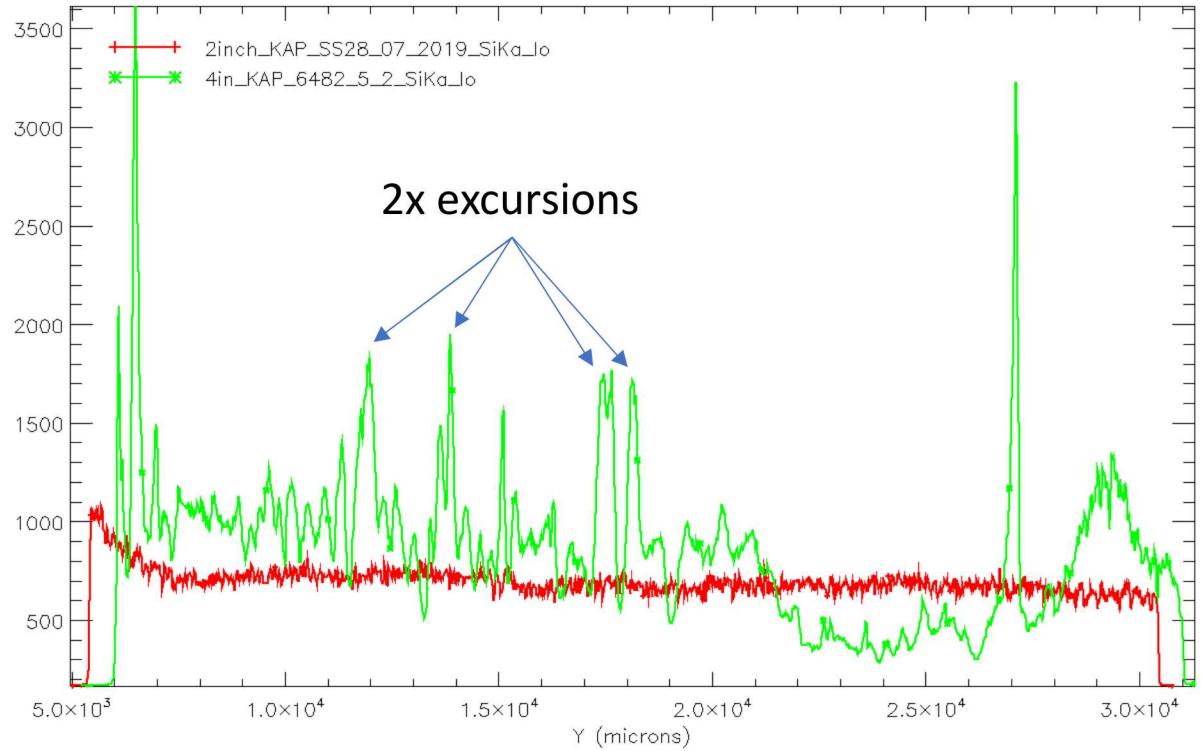
Sample from usual supplier



4” KAP 8452 5 2 (INRAD)

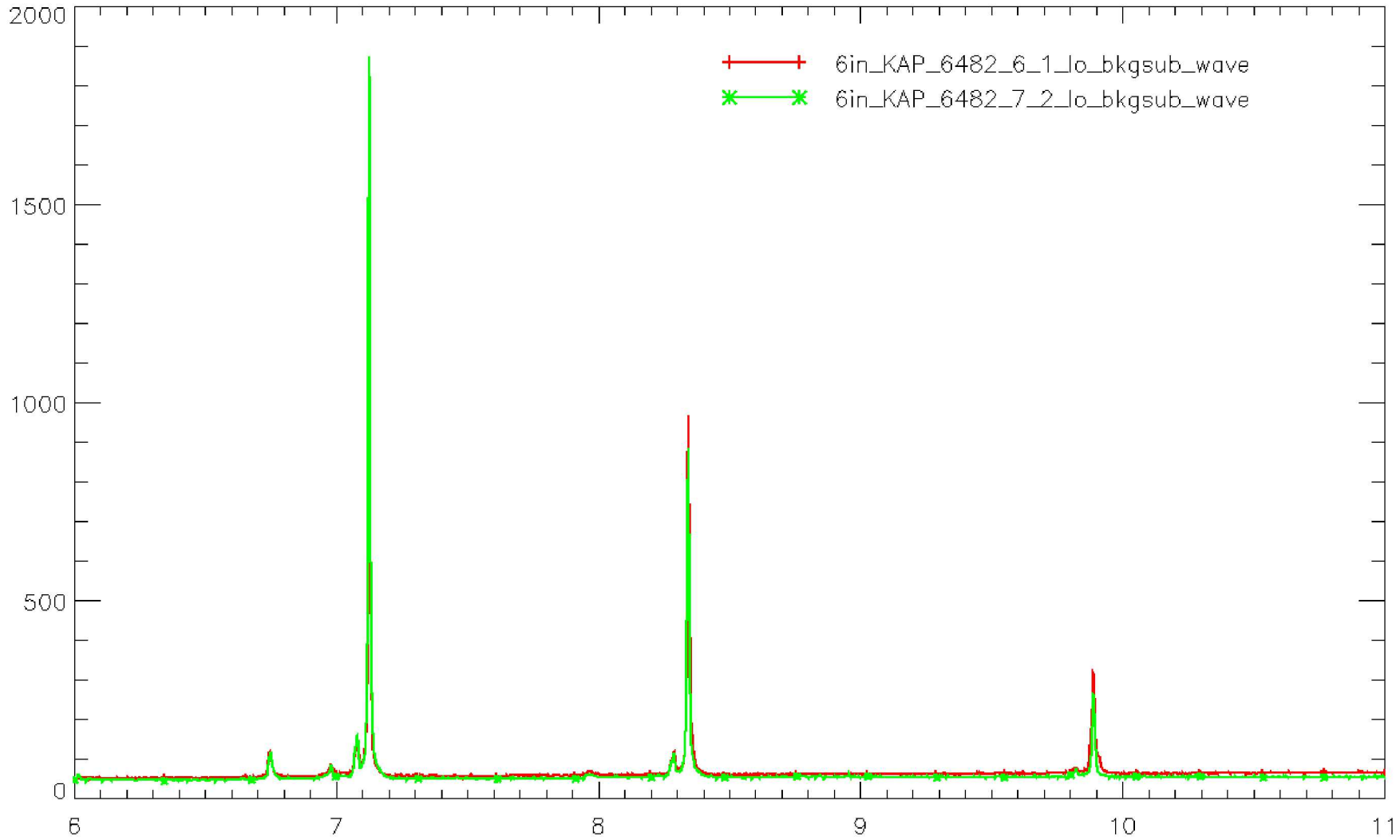


Vertical lineout through Si Kα



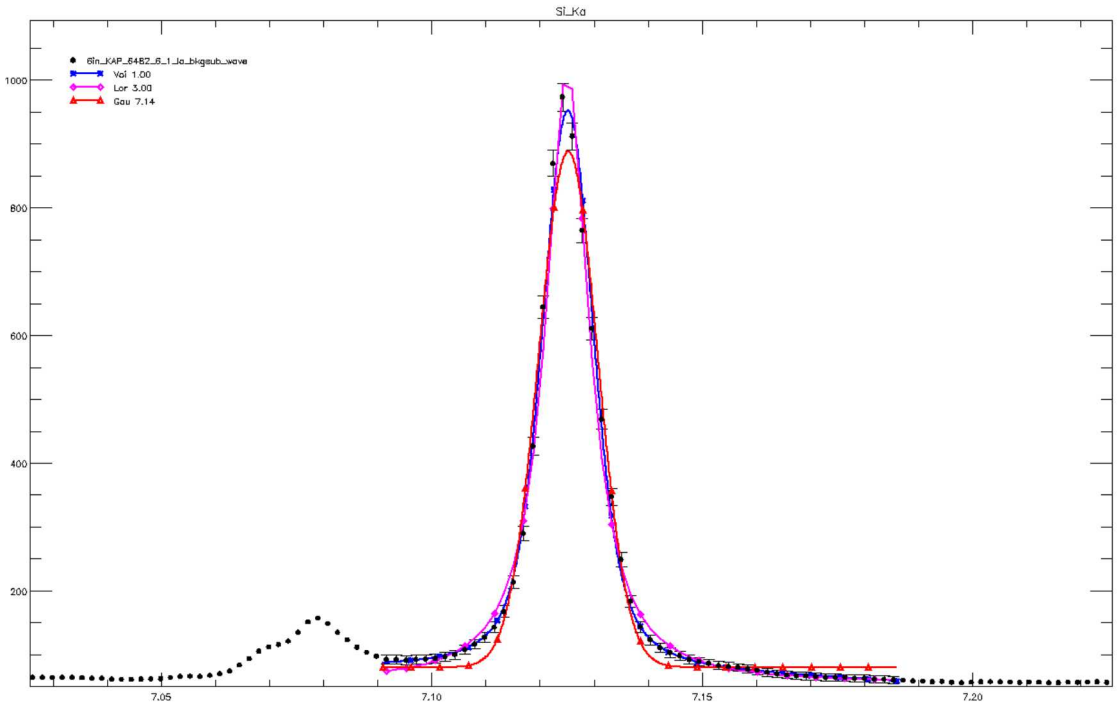
Perturbations in space-resolving direction detract from quality. Repeated excursions in signal level present challenges for quantitative spectroscopy measurements.

Lineout through central region



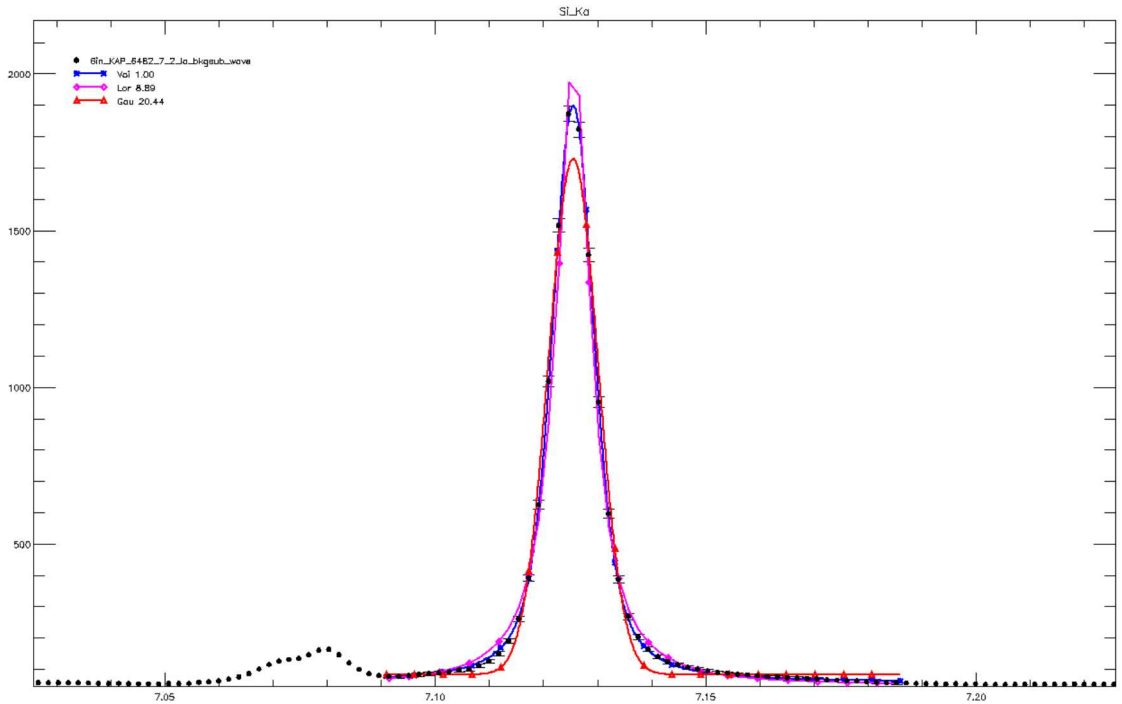
Line fits to Si Kα1

6” KAP 6482-6-1



Voigt fwhm (mAng.), error , error (%) 11.30774 0.59720 5.28136
Lorentzian FWHM FL (mAng), error , error (%) 5.25531 0.54500 10.37046
Gaussian FWHM FG (mAng), error , error (%) 8.13868 0.49408 6.07076

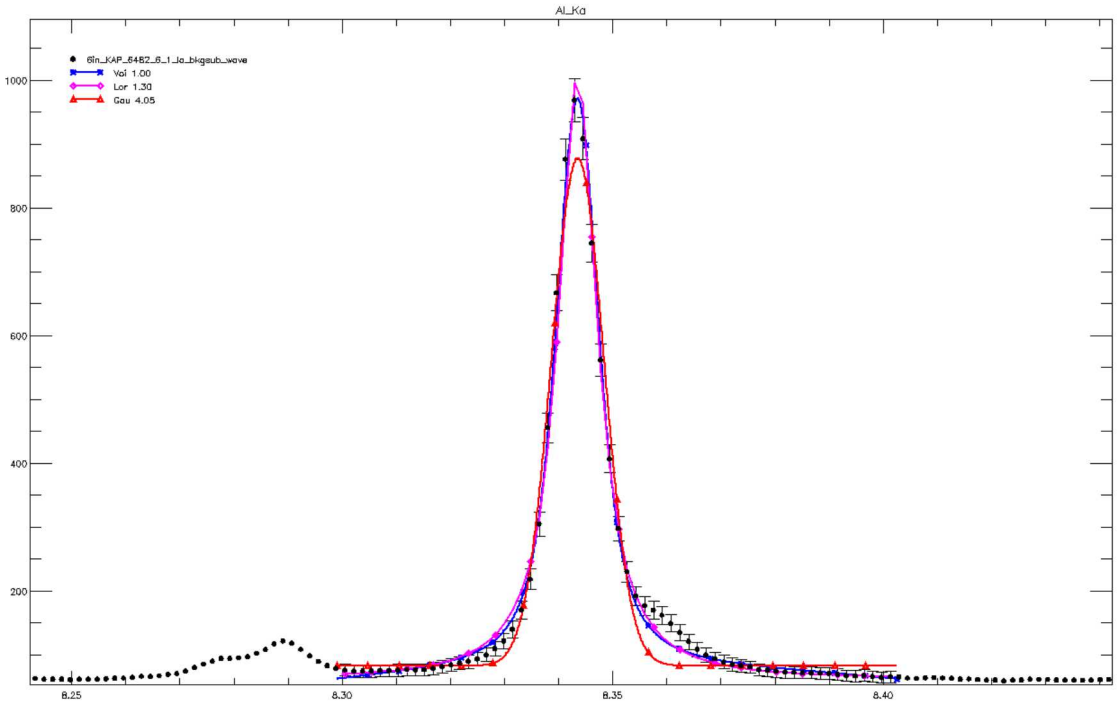
6” KAP 6482-7-2



Voigt fwhm (mAng.), error , error (%) 9.28261 0.21658 2.33318
Lorentzian FWHM FL (mAng), error , error (%) 4.99229 0.16775 3.36028
Gaussian FWHM FG (mAng), error , error (%) 6.19218 0.19459 3.14251

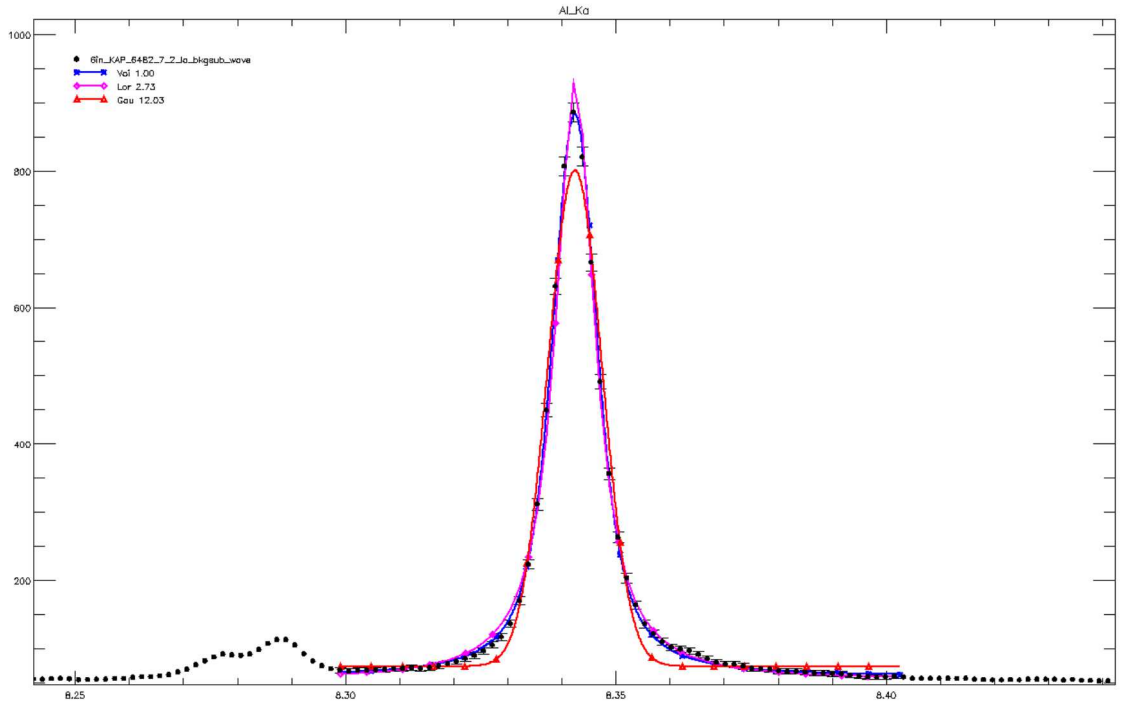
Line fits to Al Kα1

6” KAP 6482-6-1



Voigt fwhm (mAng.), error , error (%) 9.48205 0.85788 9.04736
Lorentzian FWHM FL (mAng), error , error (%) 6.21853 0.67775 10.89894
Gaussian FWHM FG (mAng), error , error (%) 5.43511 0.78103 14.37016

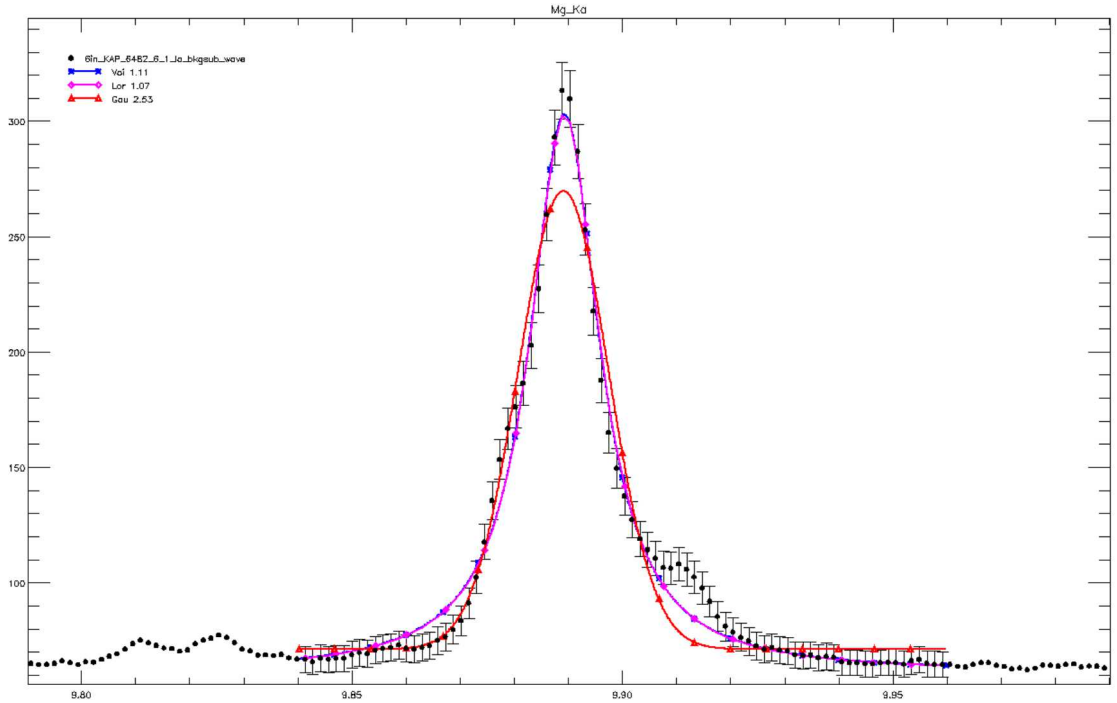
6” KAP 6482-7-2



Voigt fwhm (mAng.), error , error (%) 9.93867 0.32972 3.31756
Lorentzian FWHM FL (mAng), error , error (%) 6.67366 0.23868 3.57643
Gaussian FWHM FG (mAng), error , error (%) 5.56254 0.31508 5.66438

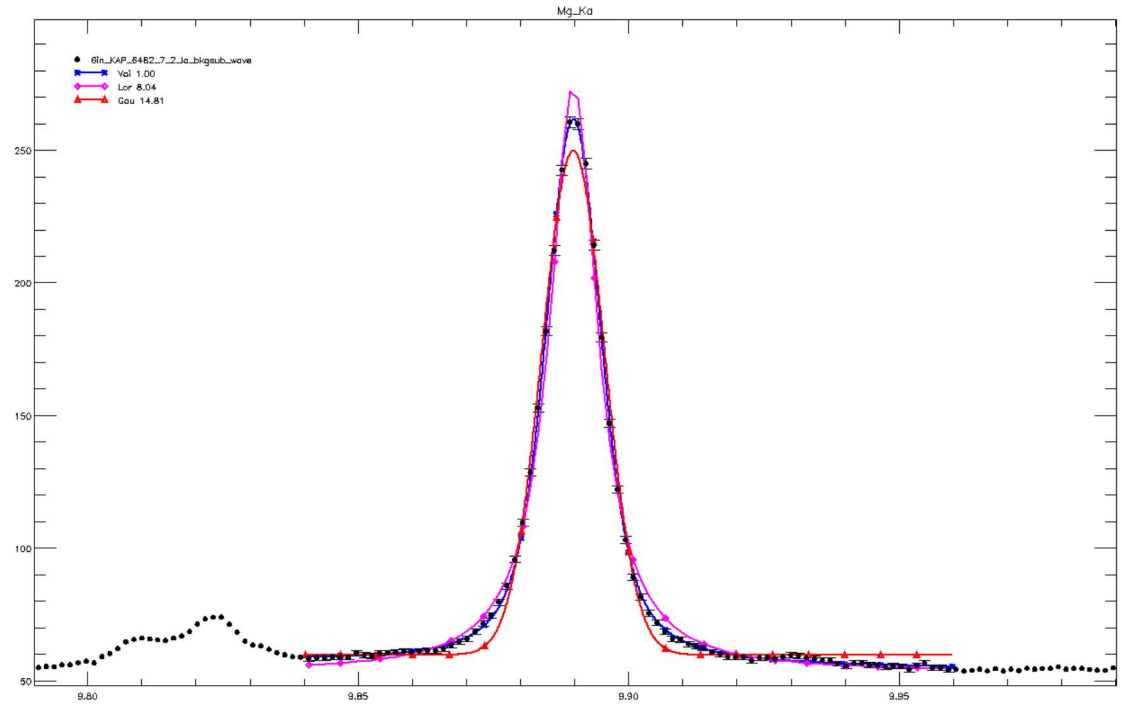
Line fits to Mg Kα1

6” KAP 6482-6-1



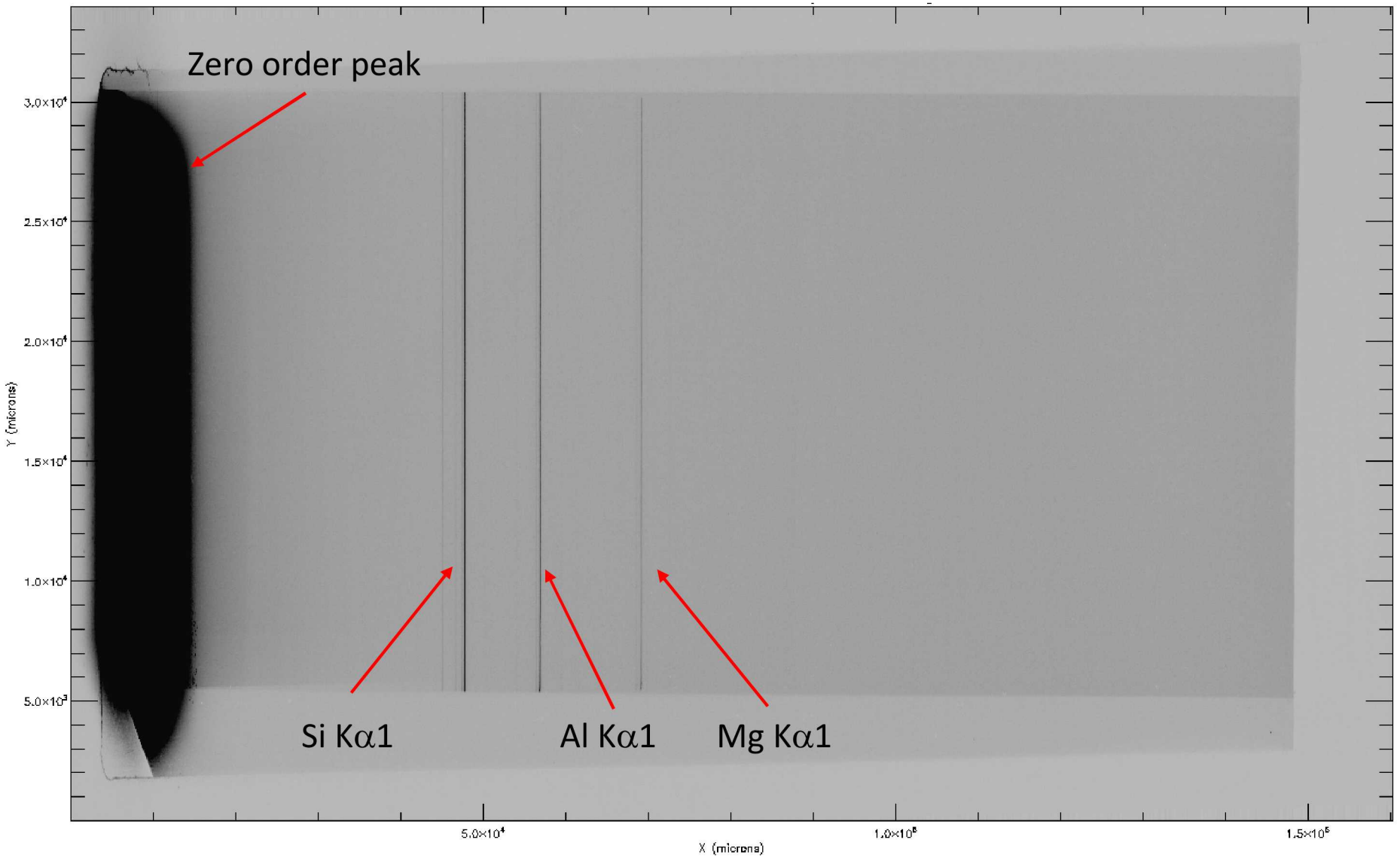
Voigt fwhm (mAng.), error , error (%) 15.74677 0.00005 0.00029
Lorentzian FWHM FL (mAng), error , error (%) 15.72980 0.00003 0.00022
Gaussian FWHM FG (mAng), error , error (%) 0.49805 0.00042 0.08526

6” KAP 6482-7-2

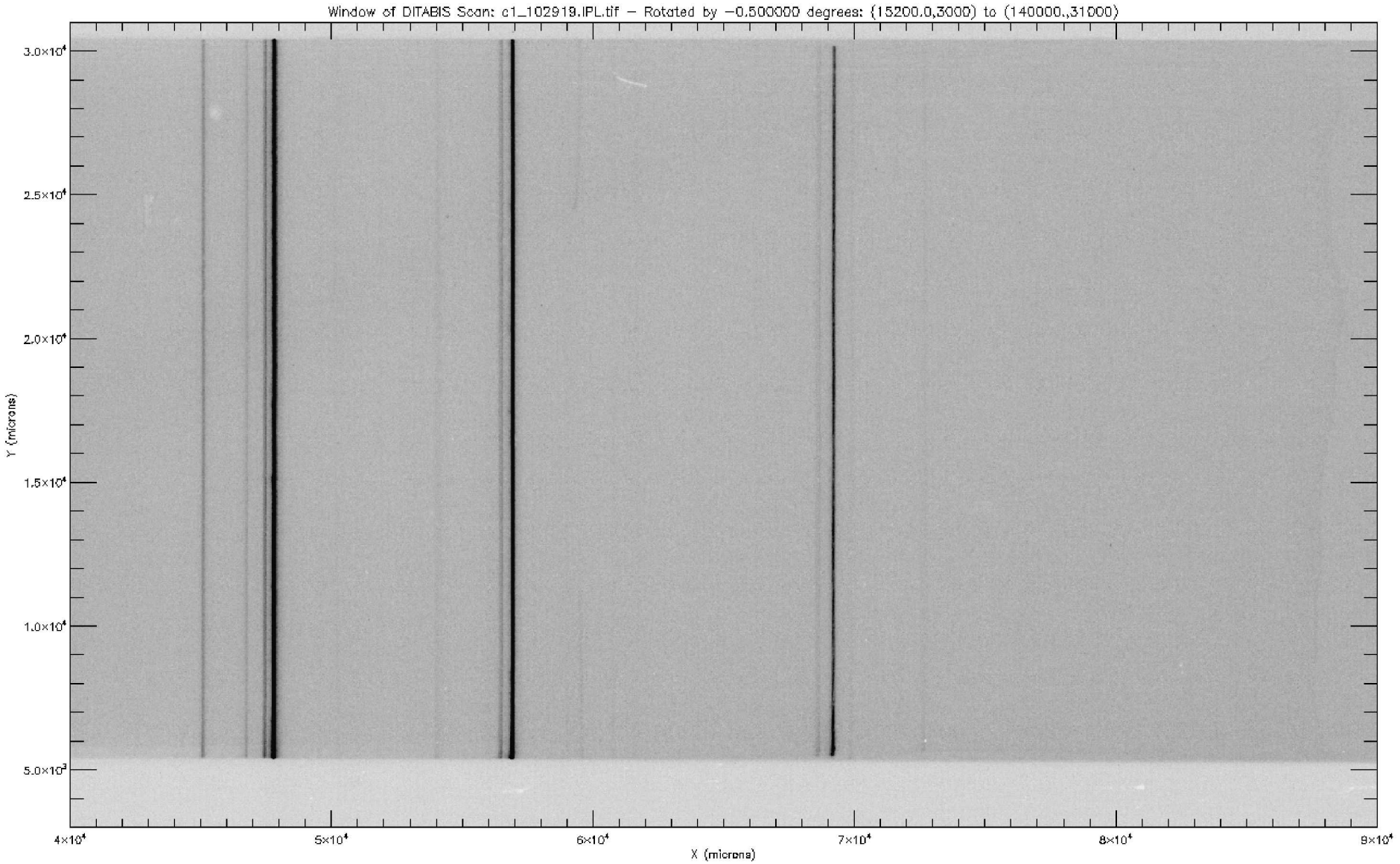


Voigt fwhm (mAng.), error , error (%) 12.28170 0.23901 1.94607
Lorentzian FWHM FL (mAng), error , error (%) 6.55803 0.20325 3.09930
Gaussian FWHM FG (mAng), error , error (%) 8.22793 0.20540 2.49642

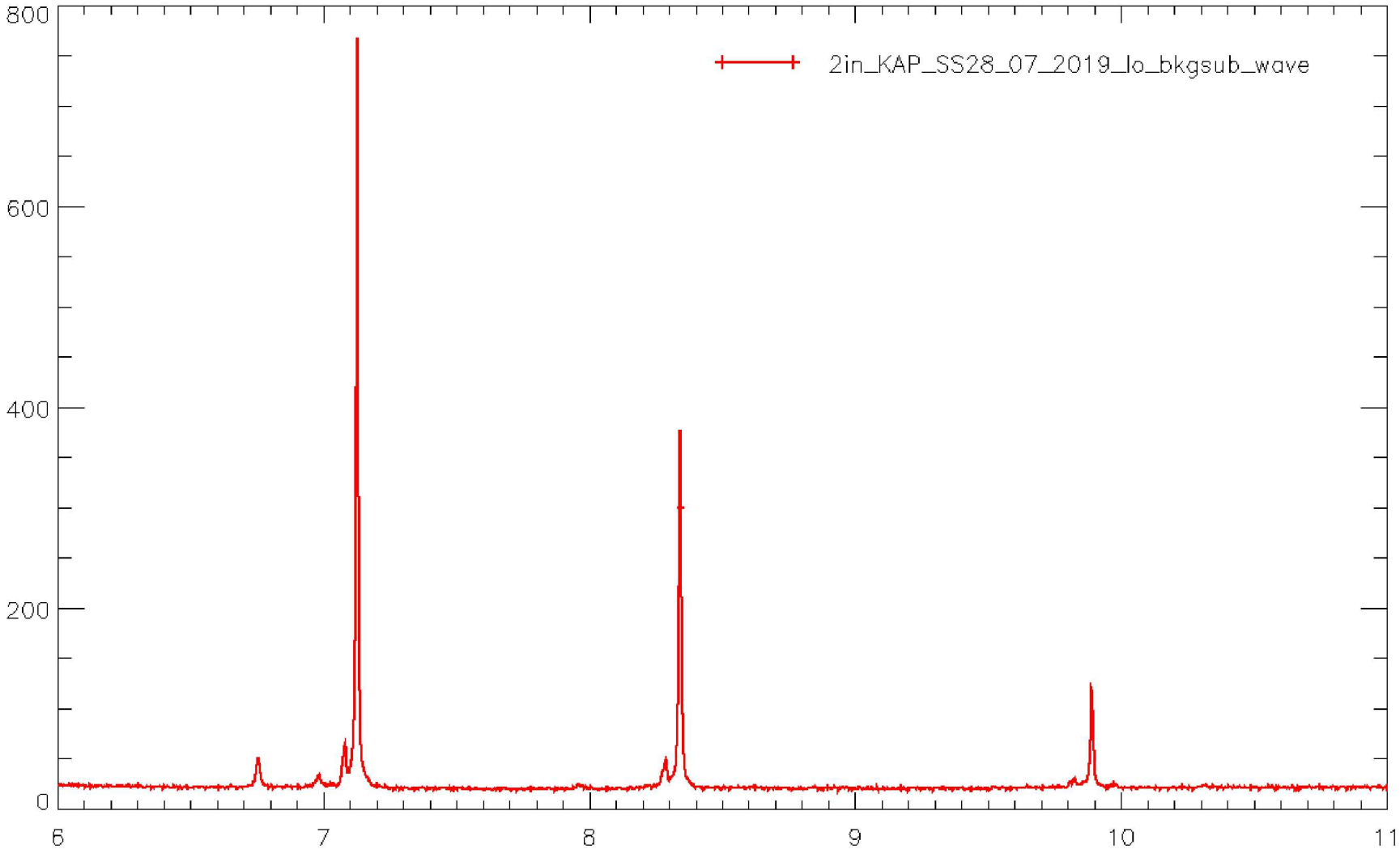
2” KAP crystal used on Z experiments
(from usual supplier)



2” KAP SS28 07 2019 Detail



2” KAP SS28 07 2019 Detail Lineout



Line widths in milli Angstroms from Voigt fits

Crystal ID	6482-4-1	6482-5-2	6482-6-1	6482-7-2	SS28-07-2019
Type	4” KAP	4” KAP	6” KAP	6” KAP	2” KAP
Si Kα1	10.203 ± 0.166	10.123 ± 0.284	11.291 ± 0.539	9.283 ± 0.217	9.565 ± 0.233
Al Kα1	10.786 ± 0.183	11.186 ± 0.303	9.444 ± 0.749	9.939 ± 0.330	10.380 ± 0.258
Mg Kα1	12.163 ± 0.475	11.366 ± 0.359	15.986 ± 0.054	12.282 ± 0.239	11.345 ± 0.480

Resolution (E/δE)

Crystal ID	Line	6482 4 1	6482 5 2	6482 6 1	6482 7 2	ss28 07 2019
Type	Energy (keV)	Resolution	Resolution	Resolution	Resolution	Resolution
Si Kα1	1.740	698	704	630	768	745
Al Kα1	1.487	773	746	880	839	803
Mg Kα1	1.254	813	870	628	805	872

Summary

- Crystal resolution is on par with nominal crystals used routinely at Z
- Spectral lines are straight showing acceptable waviness
- Broken (discontinuous) spectral lines detract from quality creating variations of 2x or more in intensity in the space resolving direction over a single spectral feature
- Circular features from bubbles or contaminants are too numerous
- Many issues, possibly due to crystal quality, substrate preparation, environmental cleanliness, or mounting technique, render current KAP samples unsuitable for quantitative spectroscopy

Cleanroom Definition

Class	Maximum particles/m^3 [a]						FED STD 209E
	≥0.1 µm	≥0.2 µm	≥0.3 µm	≥0.5 µm	≥1 µm	≥5 µm	equivalent
ISO 1	10[b]	[d]	[d]	[d]	[d]	[e]	
ISO 2	100	24[b]	10[b]	[d]	[d]	[e]	
ISO 3	1,000	237	102	35[b]	[d]	[e]	Class 1
ISO 4	10,000	2,370	1,020	352	83[b]	[e]	Class 10
ISO 5	100,000	23,700	10,200	3,520	832	[d,e,f]	Class 100
ISO 6	1,000,000	237,000	102,000	35,200	8,320	293	Class 1,000
ISO 7	[c]	[c]	[c]	352,000	83,200	2,930	Class 10,000
ISO 8	[c]	[c]	[c]	3,520,000	832,000	29,300	Class 100,000
ISO 9	[c]	[c]	[c]	35,200,000	8,320,000	293,000	Room air