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Prospects and Issues for Spaceborne Imaging Spectrometers that Achieve AVIRIS Levels of Performance

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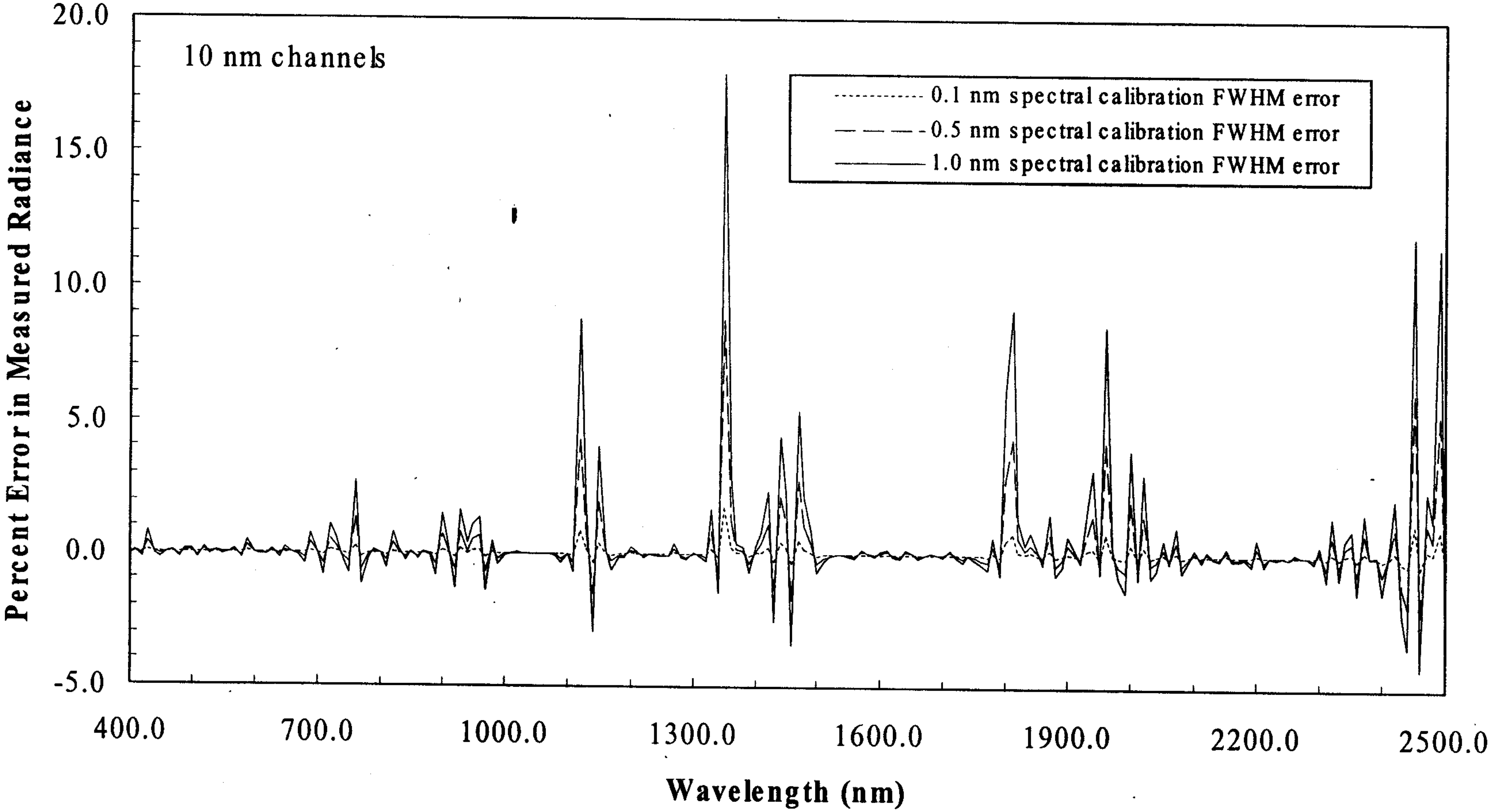

From: R. O. Green, Appl. Opt. **37**, 683-690 (1998)

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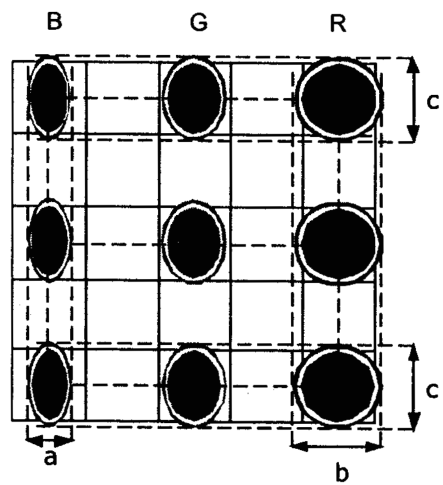
Schematic of ideal spectrum produced by a pushbroom imaging spectrometer



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Imaging spectrometers provide spectrum of every pixel in a two-dimensional image

Two basic forms:
- Whiskbroom
- Pushbroom

Whiskbroom:
- spectrometer input is a pinhole
- scans point in raster fashion to acquire 2-D image
- uses linear detector array ('easy' calibration)
- all ground points have their spectra recorded by same one array
- good SNR for air, inadequate for space systems

Pushbroom:
- spectrometer input is a slit
- uses motion perpendicular to slit to acquire 2-D image
- uses area array (difficult calibration)
- is equivalent to many different spectrometers for each point on the slit (row of array)
- has adequate SNR for space systems

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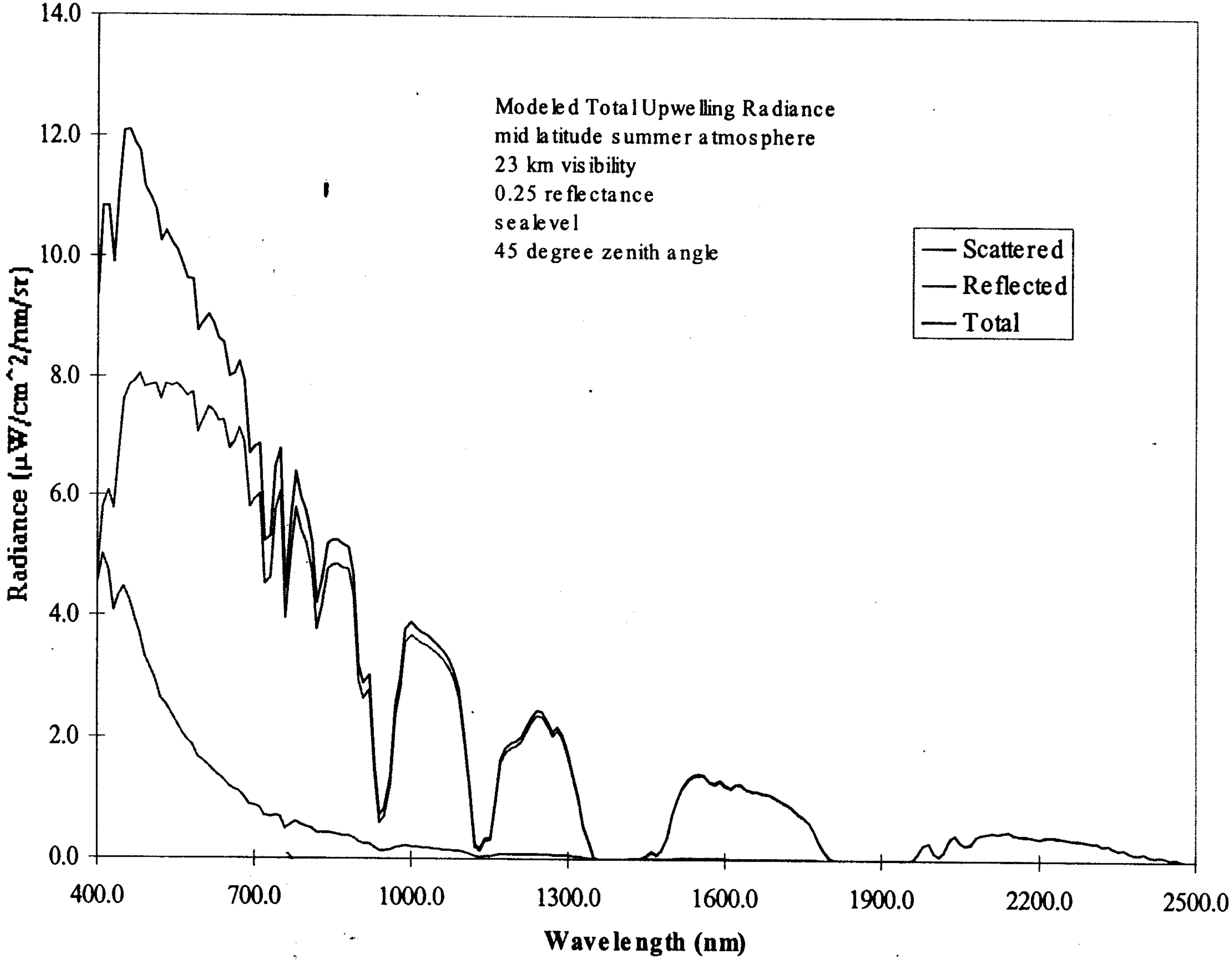
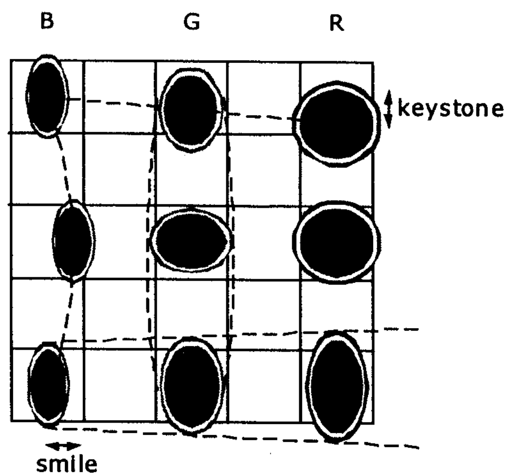

Modeled Total Upwelling Radiance
mid latitude summer atmosphere
23 km visibility
0.25 reflectance
sealevel
45 degree zenith angle
Scattered
Reflected
Total
Radiance (µW/cm^2/nm/sr)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
400.0
700.0
1000.0
1300.0
1600.0
1900.0
2200.0
2500.0
Wavelength (nm)

Schematic of real spectrum from a pushbroom imaging spectrometer



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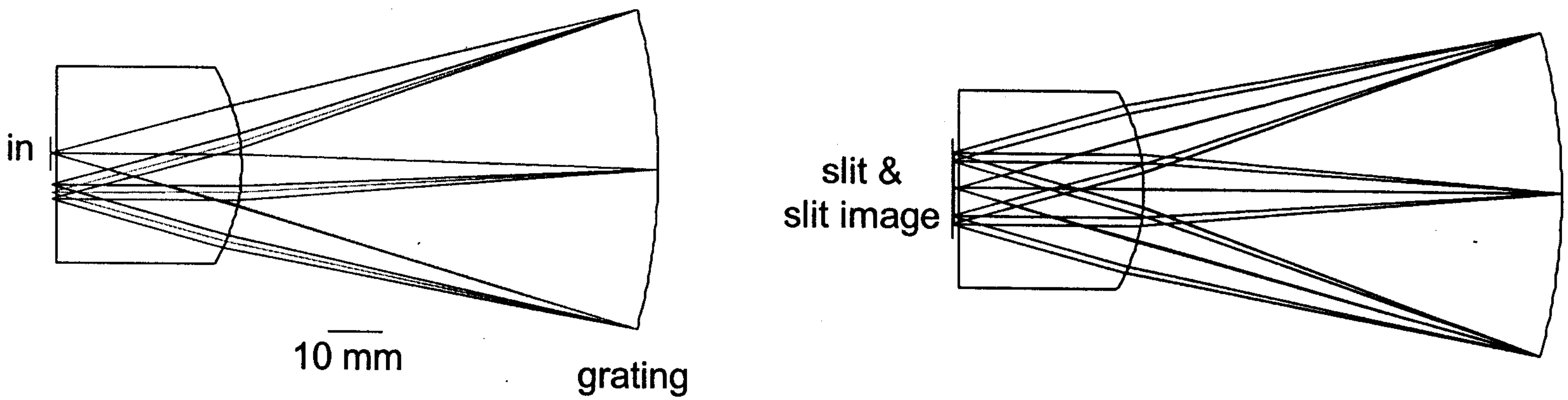
Dyson spectrometer example



Spectrometer example first-order parameters

	Offner	Dyson
Spectral range	1 – 2.5 µm	1 – 2.5 µm
Spectral sampling	10 nm	10 nm
Pixel size (square)	27 µm	18 µm
Slit length	19.44 mm	12.96 mm
No. of spatial pixels	720	720
f-number	4	1.3

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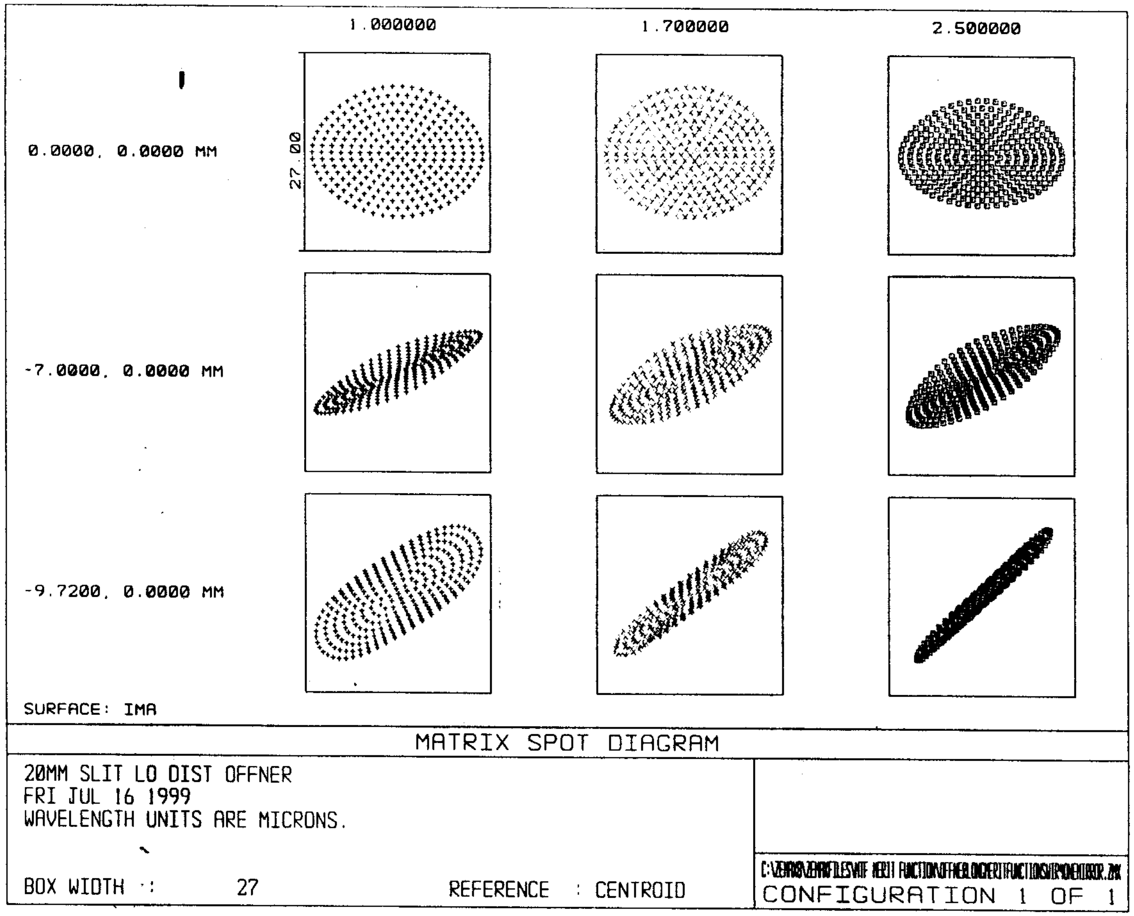
Spot diagrams for Offner example



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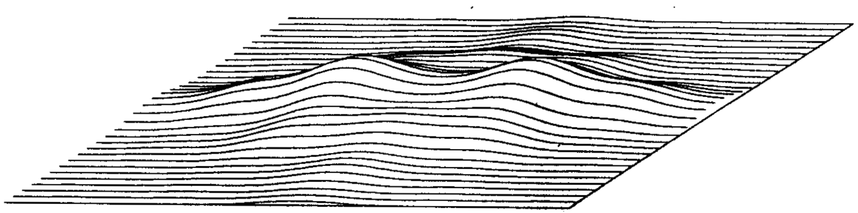
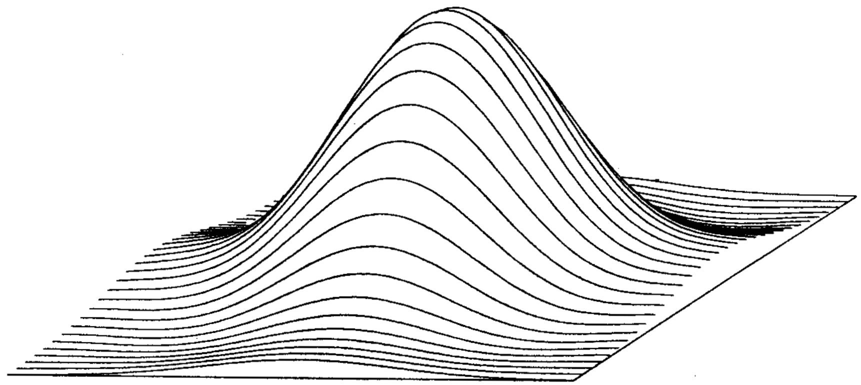
Worst-case PSF's for Offner example



27 μm

1000 nm



27 μm

2500 nm

(Strehl: 0.73)

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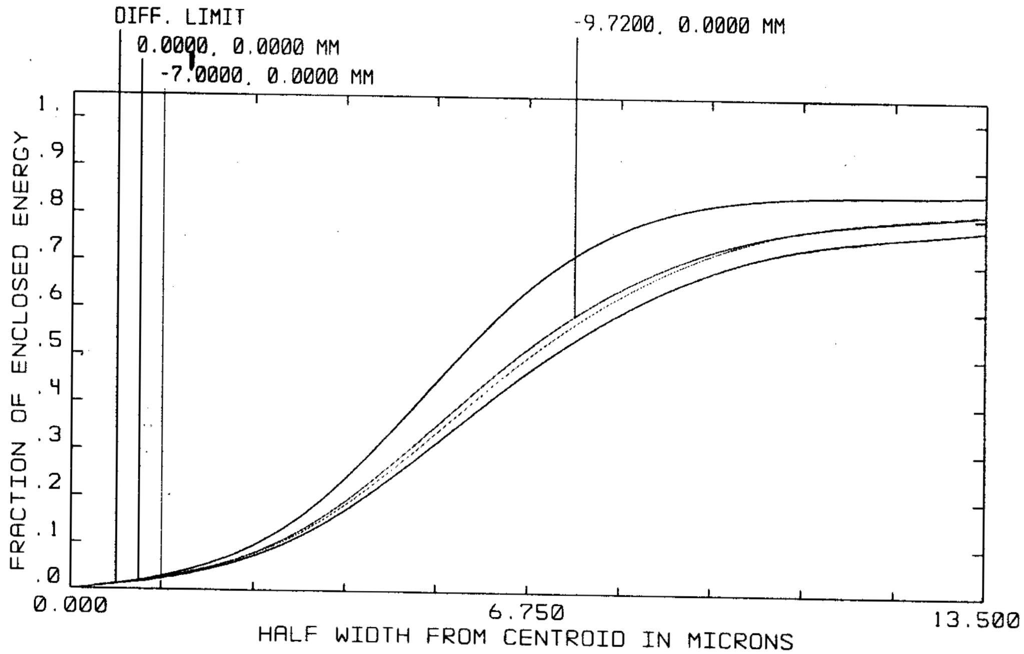

FFT DIFFRACTION ENSQUARED ENERGY

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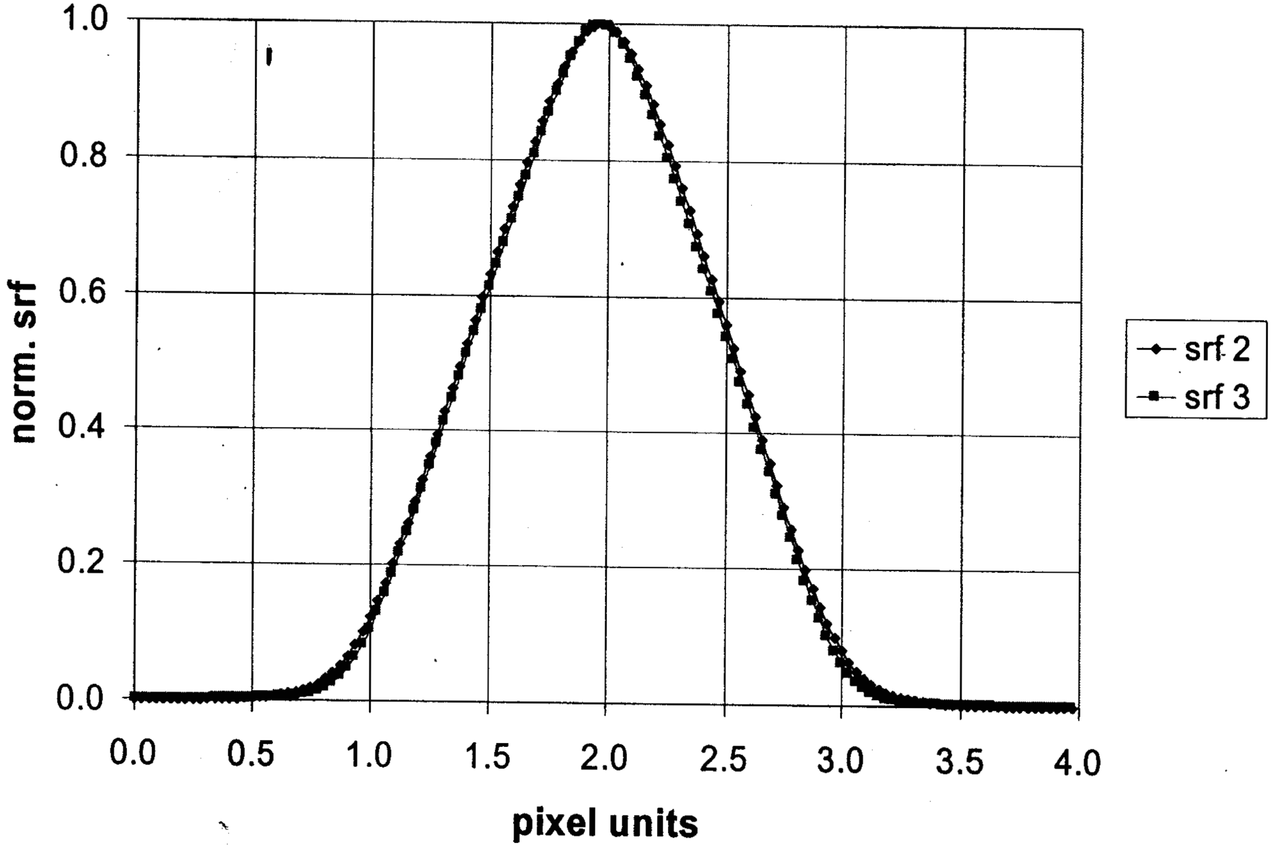
Worst-case SRF variation for Offner example



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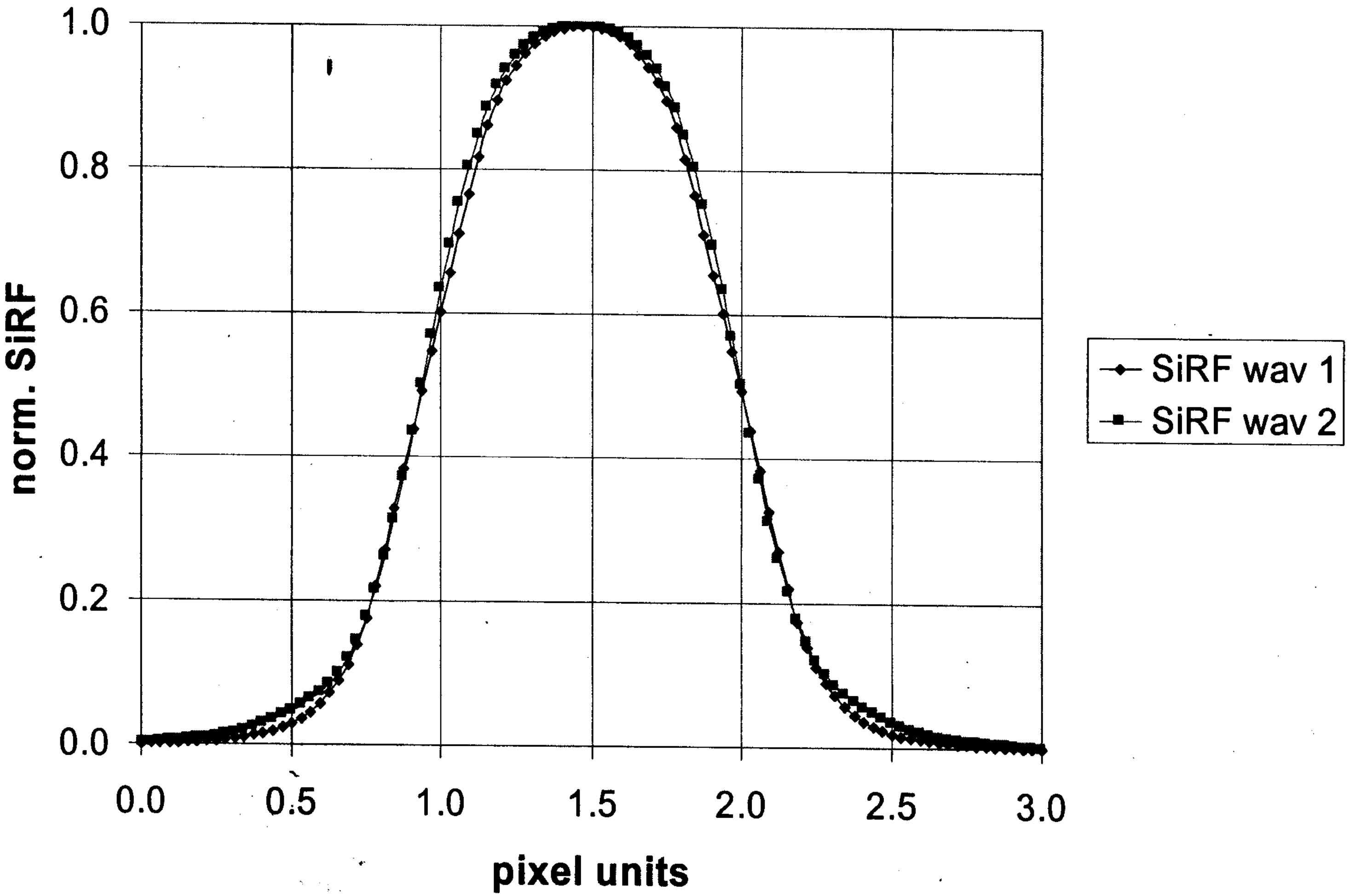
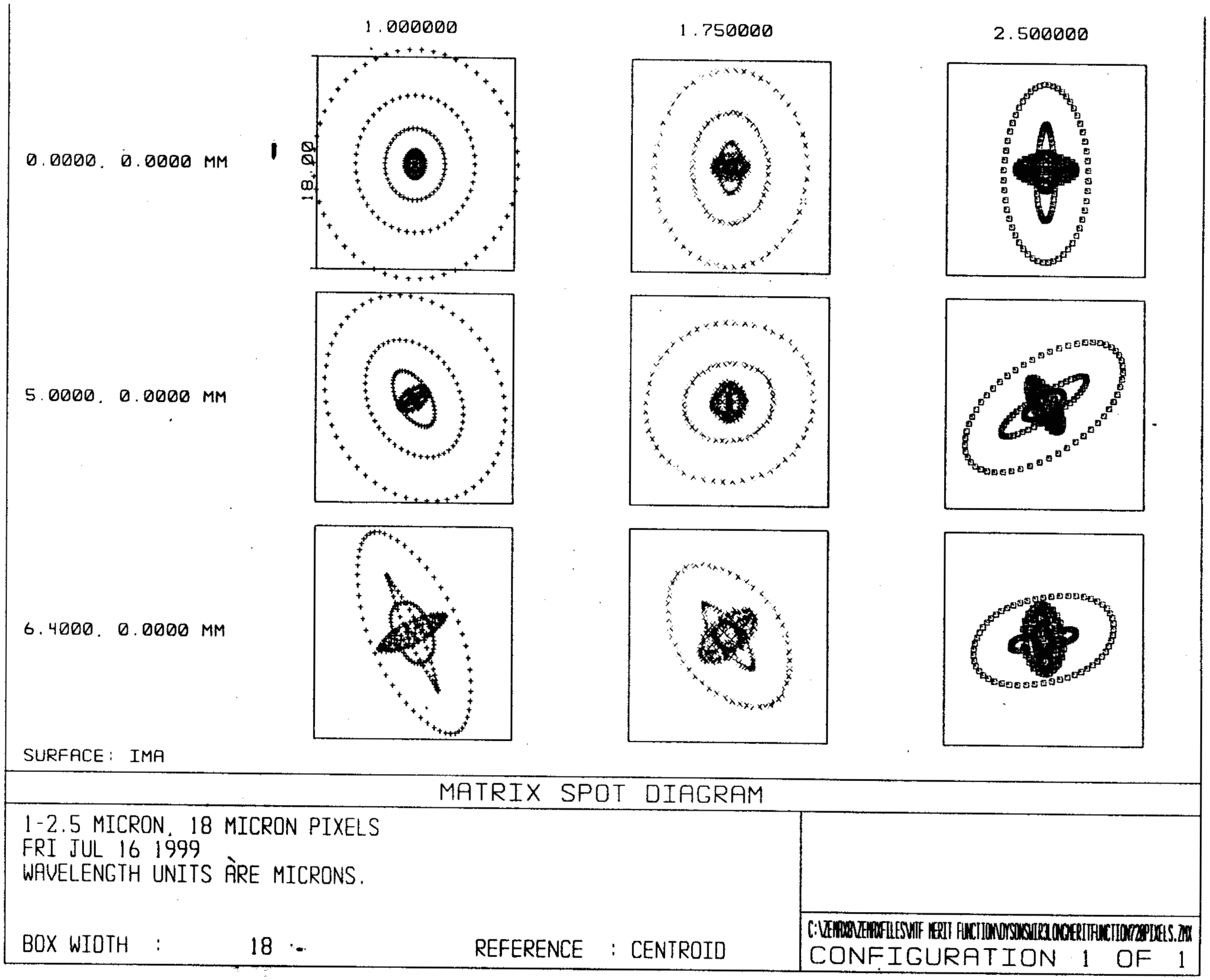
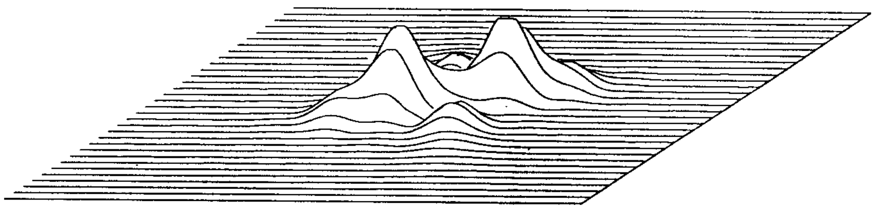
Worst-case SiRF variation for Offner example



Spot diagrams for Dyson example

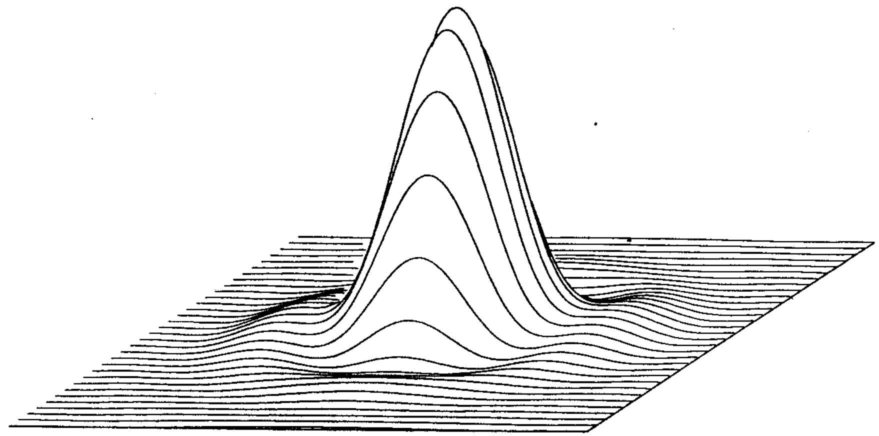


Worst-case PSF's for Dyson example



18 μm

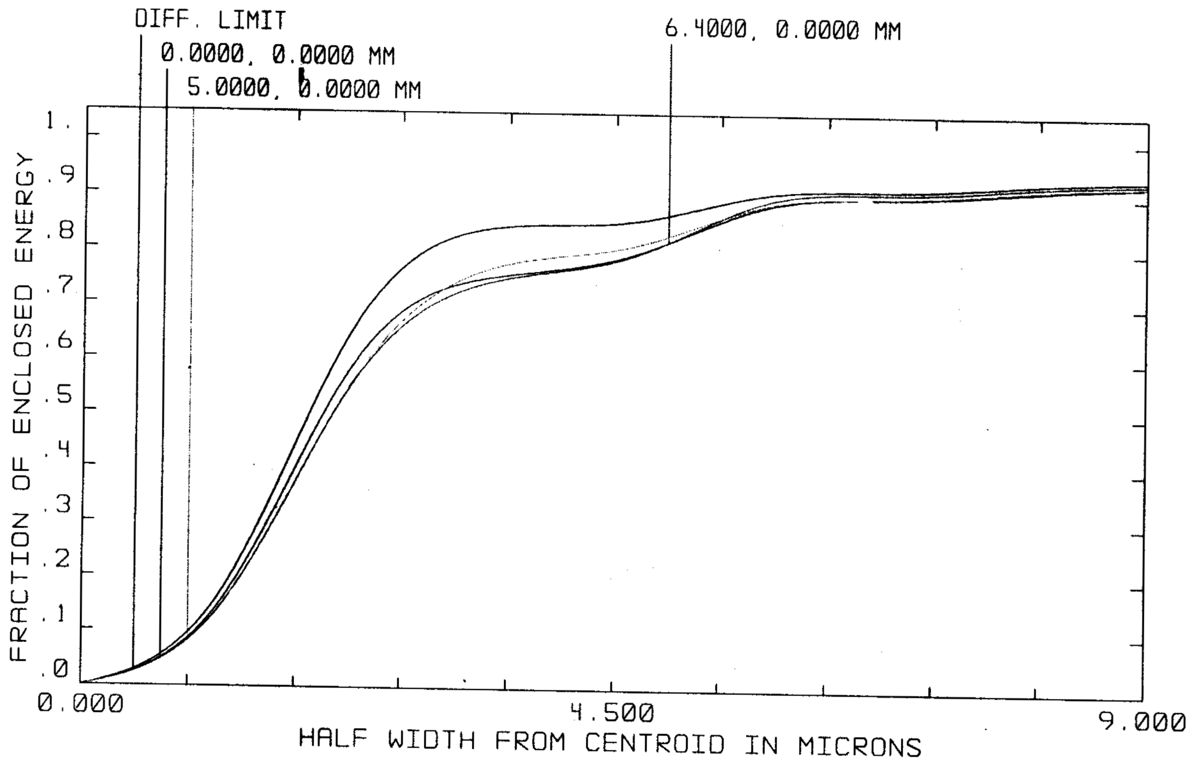
1000 nm



18 μm

2500 nm

(Strehl: 0.85)



FFT DIFFRACTION ENSQUARED ENERGY

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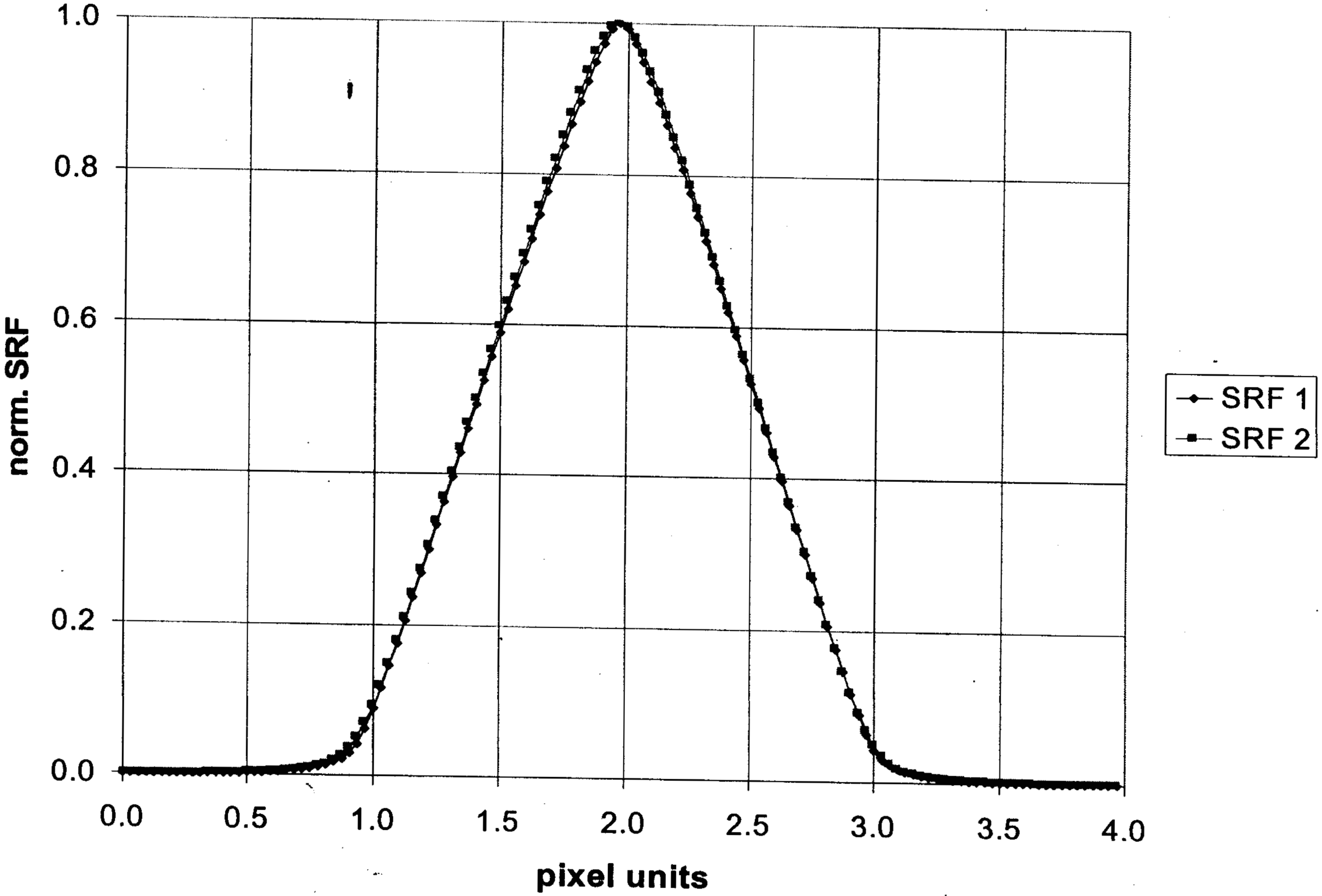
Worst-case SRF variation for Dyson example



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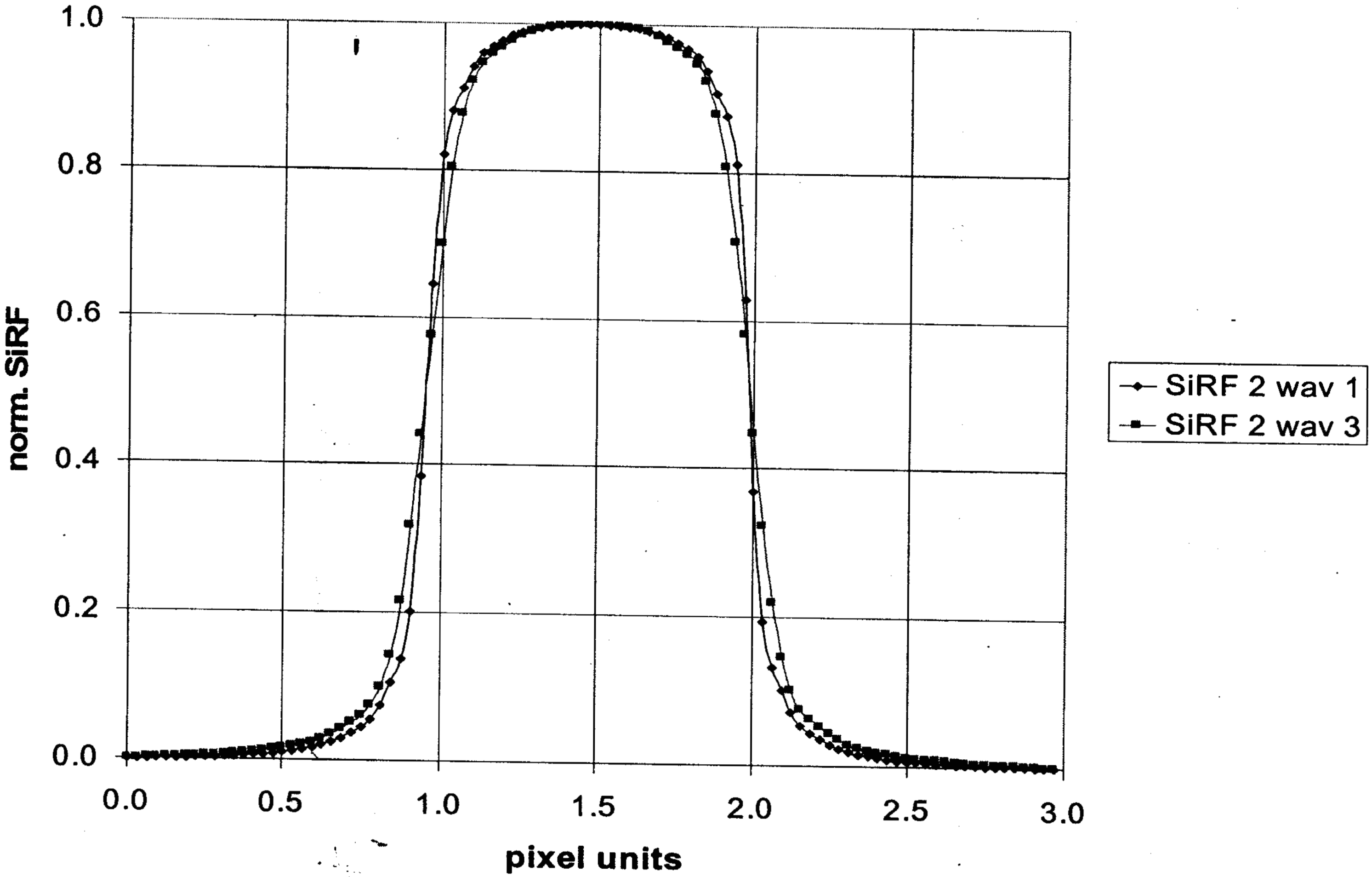
Worst-case SiRF variation for Dyson example



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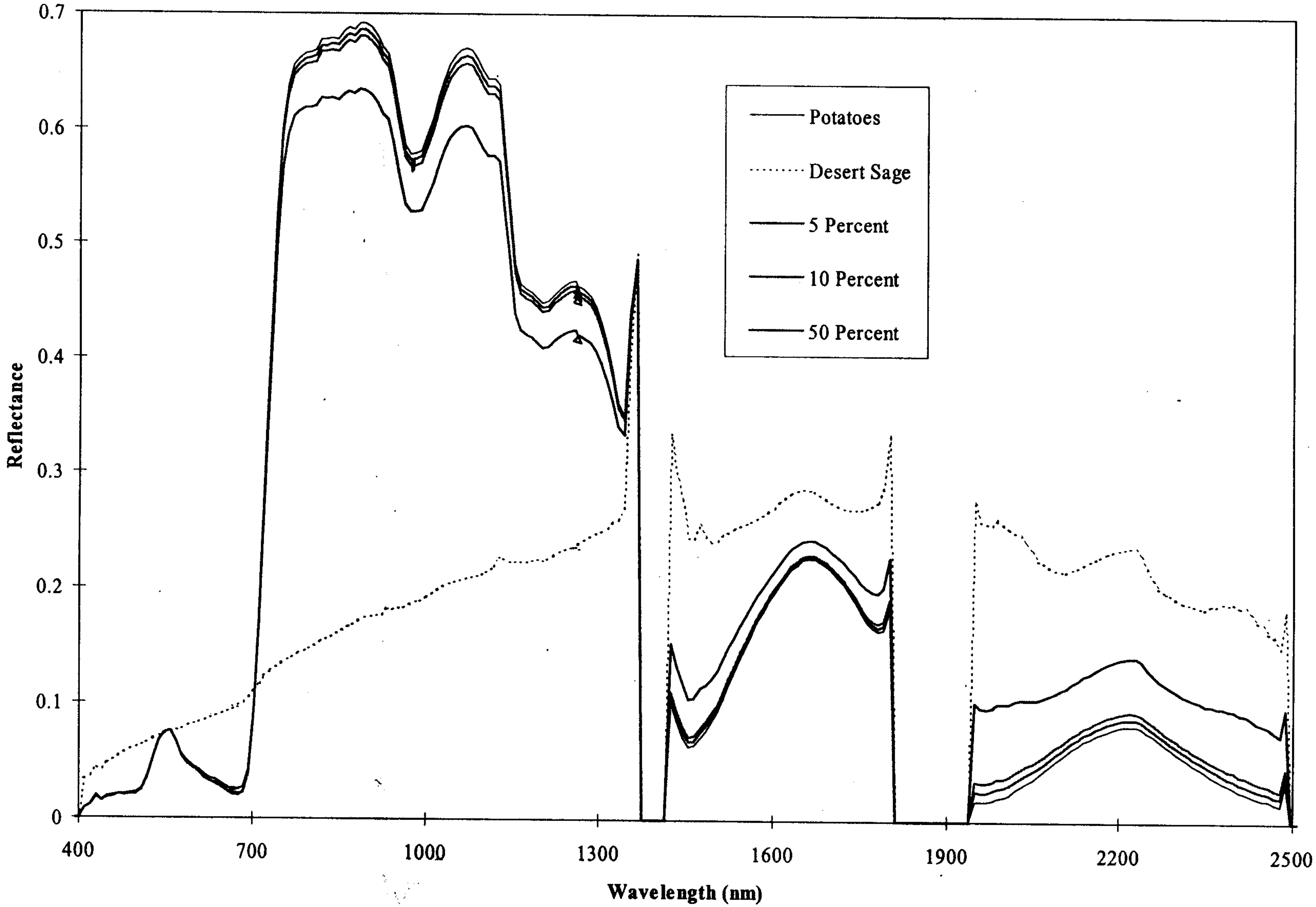
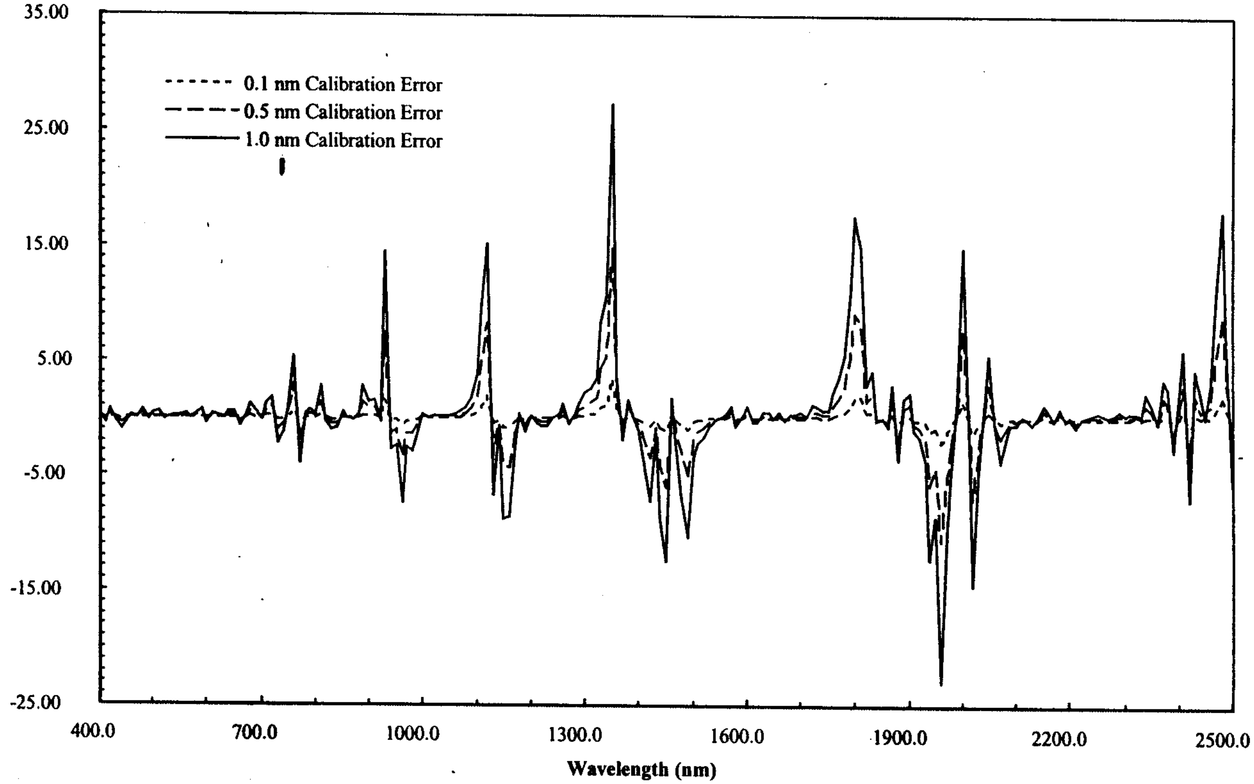
Imaging Spectrometer Modeled Spatial Keystone Effect





Radiance error induced by channel center wavelength position

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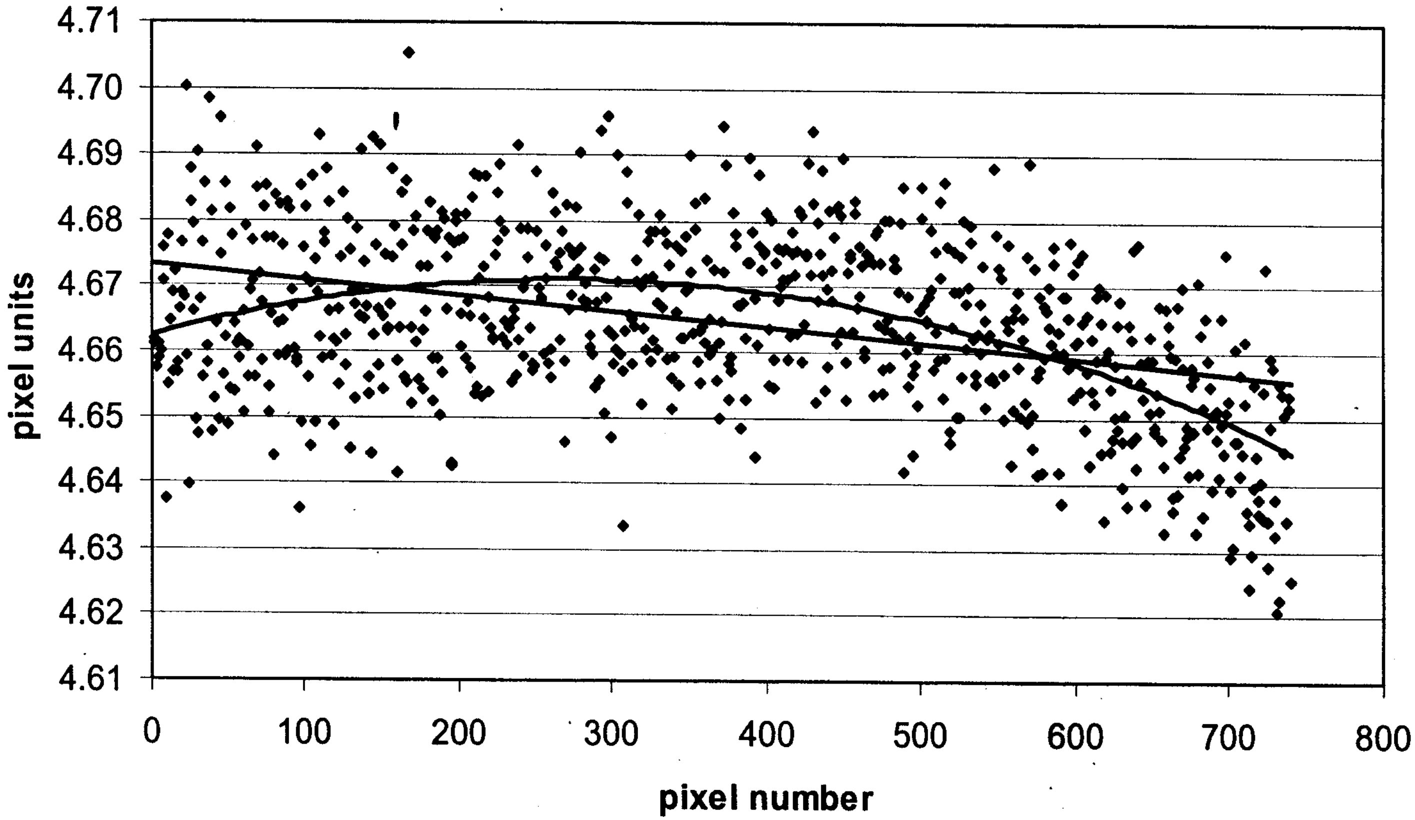

4.71
4.70
4.69
4.68
4.67
4.66
4.65
4.64
4.63
4.62
4.61
pixel units
0
100
200
300
400
500
600
700
800
pixel number

Spectrometer Design Performance

	Strehl	PSF energy in pixel	MTF (tan.)	MTF (sag.)	Smile	Keystone
400 nm	0.43-0.84	> 94%	0.86-0.93	0.93-0.95	1.8%	
1000 nm	0.85-0.90	> 90%	0.83-0.86	0.84-0.85	1.5%	1%

Offner Grating Spectrometer

- Can operate at relatively low f# (>~f/2)
- Accepts a long slit
- It has very small distortion in both spectral and spatial directions if appropriately optimized
- It has only three (two) optical surfaces
- Can be designed with spherical and centered surfaces (ease of fabrication, can reach theoretical performance)
- Utilizes high-performance E-beam gratings

Dyson Grating Spectrometer

- Can operate at very low f# (<f/1)
- Accepts reasonably long slit
- It has very small distortion in both spectral and spatial directions if appropriately optimized
- It has only three optical surfaces
- Simple to align (can reach theoretical performance)
- Utilizes blazed holographic or x-ray lithography gratings (experimental)

Offner vs. Dyson

- Speed difference favors Dyson (but typically smaller pixels)
- Offner is all reflective, can be made with advanced materials (SiC) for ‘easy’ athermalization
- Grating technology for small convex gratings is better developed than for large, steep, concave gratings
- Antireflection coatings are needed for Dyson – can limit useful spectral range
- Ghosts can be a problem with Dyson, analysis needed
- Dyson can handle greater dispersion/better spectral resolution
- Dyson can be more compact

Offner spectrometer example