The SHIMMER Instruments: (An NSF Small Satellite Program Before the Fact)

or…

How an NSF instrument was backed into the DOD Space Test Program

Fred Roesler, University of Wisconsin

NSF AWARD ATM-961228

Development of Spatial Heterodyne Spectroscopy for Atmospheric Remote sensing

- 1995 NSF OS&E initiative (95-116)
- 627 pre-proposals reviewed
- 76 invitations to submit full proposals
- 18 final selections (2 in AER)
- Required interdisciplinary collaborators: NRL, St. Cloud, UW Astron, UW Physics
- Extra NRL $ to make SHS space worthy (if you build it, DOD might open a door somewhere-Space Test Program)

Principal Colleagues

John Harlander* - St Cloud State University

Robert Conway - U.S. Naval Research Lab

Ronald J. Reynolds* - University of Wisconsin

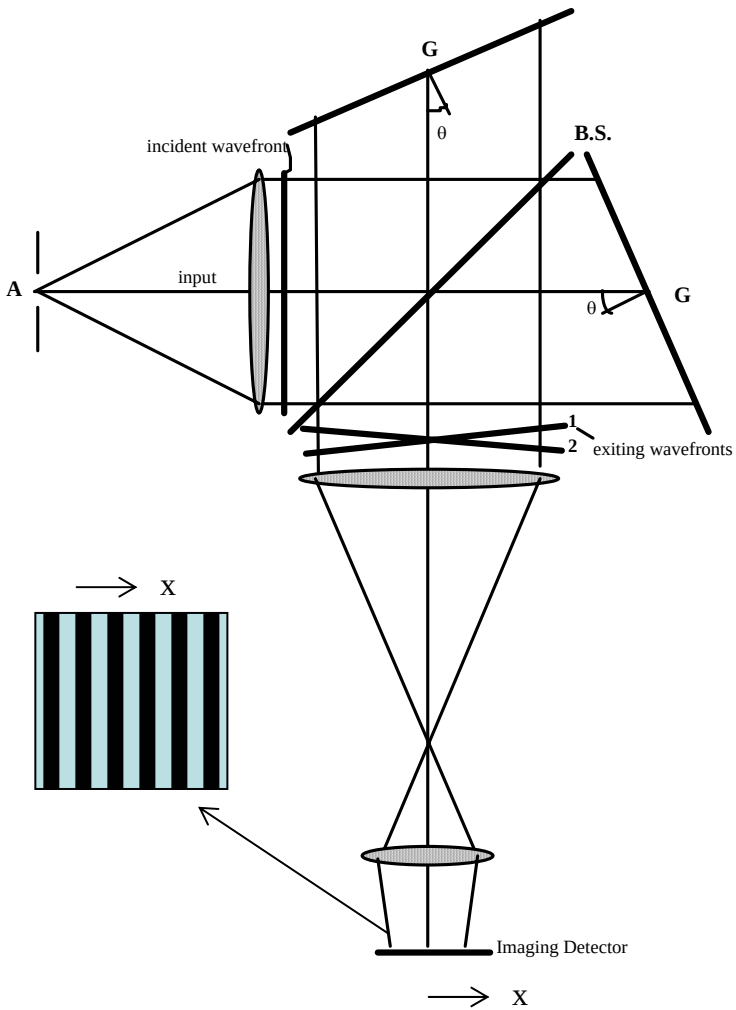
Joel Cardon – NRL (now Utah State U)

Christoph Englert - U.S. Naval Research Lab

Edwin Mierkiewicz* - University of Wisconsin

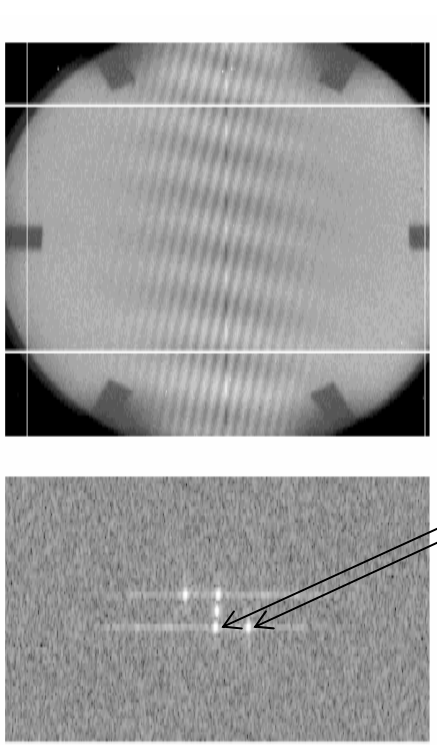
David Siskind - U.S. Naval Research Lab

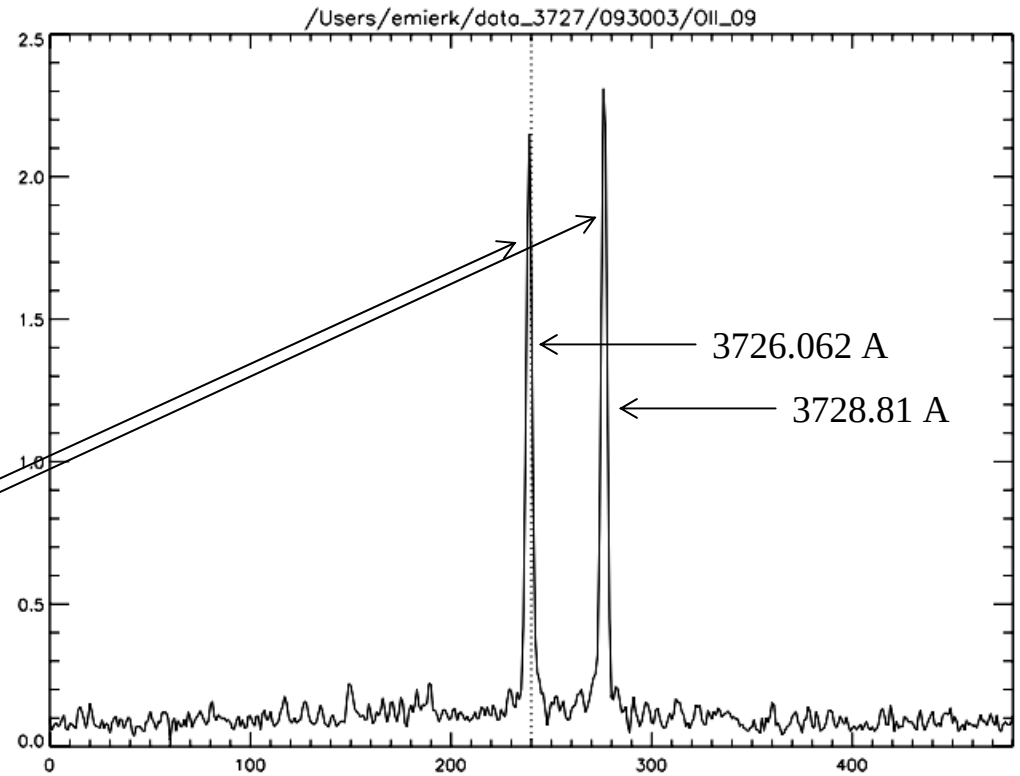
SHS properties



- No mechanical part is moved in operation
- Diffraction-limited R of the grating combination ($4W\sin\theta/\lambda$)
- Throughput is that of interference spectrometers ($\Omega = 2\pi/R$)
- Field-widening is achieved with fixed prisms in each arm ($\Omega_{fw} \approx 100\ \Omega$)
- Relaxed optical tolerances (a few λ)
- Can Phase correct post acquisition
- Pixel-limited bandwith ($N/2)(\lambda/R$)
- Cross-tilt removes ± f ambiguity
- Instantaneous spectral coverage

Example SHS Fringes and Transform





- The ambiguity between $\sigma_o + \delta\sigma$ and $\sigma_o - \delta\sigma$ can be avoided by adding a cross-tilt to the gratings.
- Wavenumbers $\sigma < \sigma_o$ are rotated clockwise, while $\sigma > \sigma_o$ are rotated counter clockwise.

SHIMMER

Spatial Heterodyne IMager of MEsospheric Radicals

Objective:

- To measure global OH resonance fluorescence (hence abundance) between 34 - 96 km

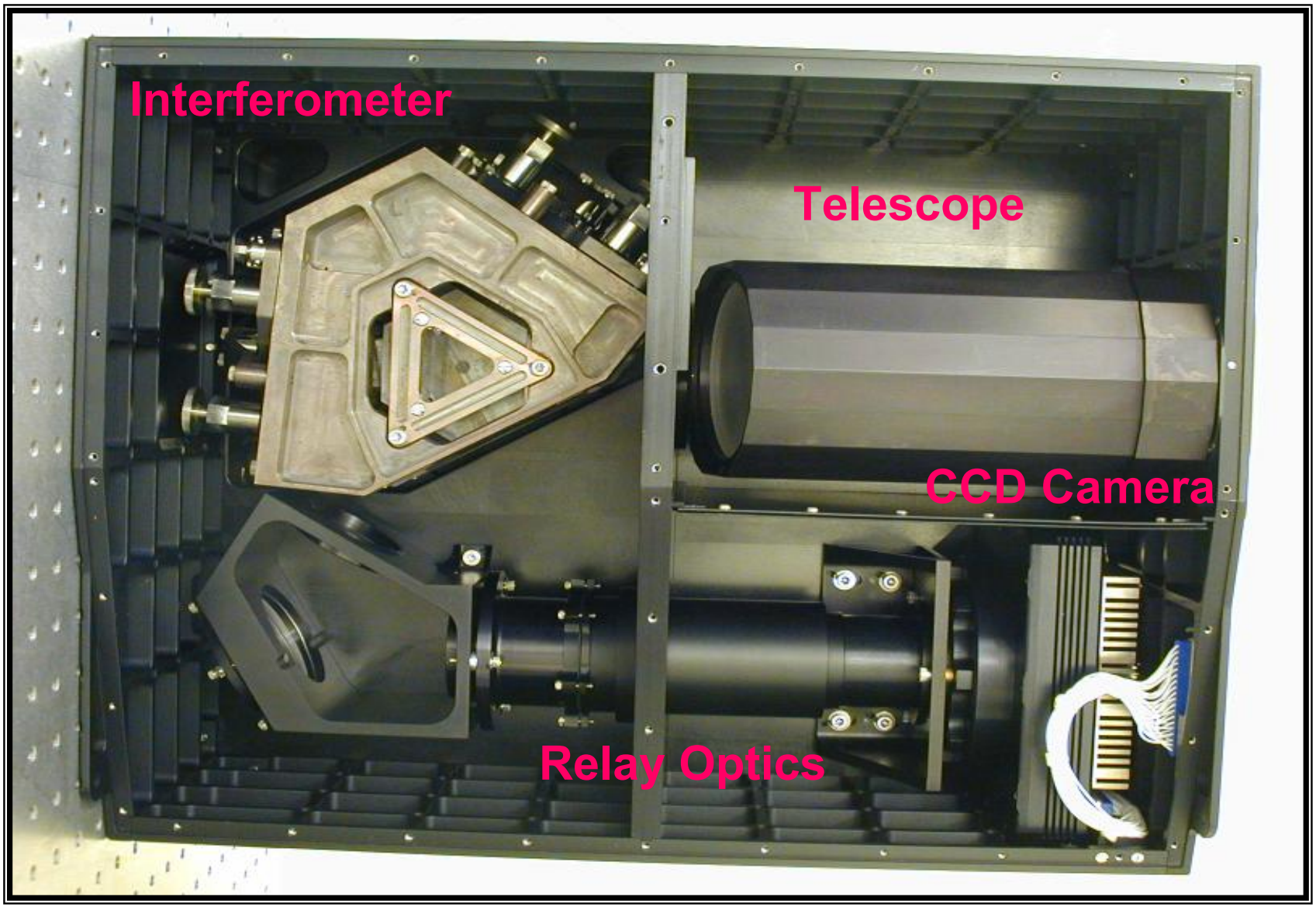
Science Motivation:

- OH is an important oxidizing agent in the Earth's atmosphere
- OH resonant scattering at 308nm was measured by MAHRSI
- Photochemical models fail to predict the observed results

Why SHS?:

- Grating instruments meeting science requirements are too large for small satellites
- The field-widened SHS achieves the requirements in a small package without moving parts
- Fabry-Perot efficiencies low at 300nm.

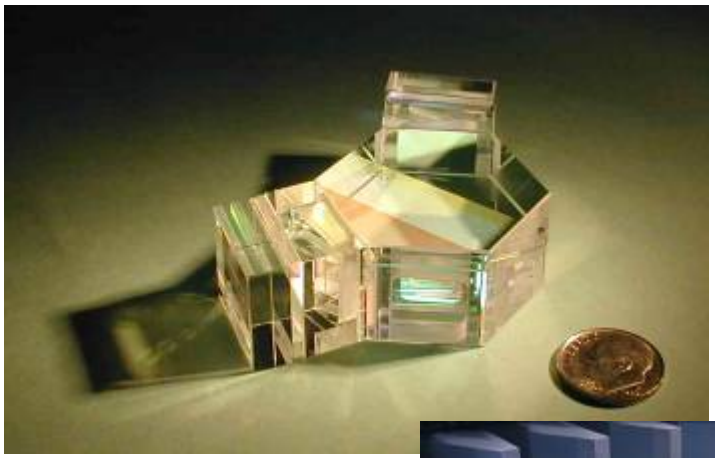
NSF-SHIMMER mid-deck SHS

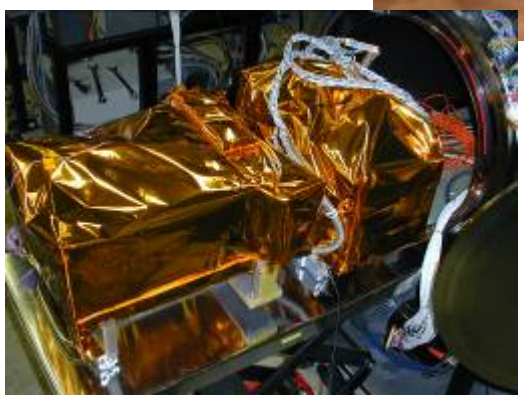


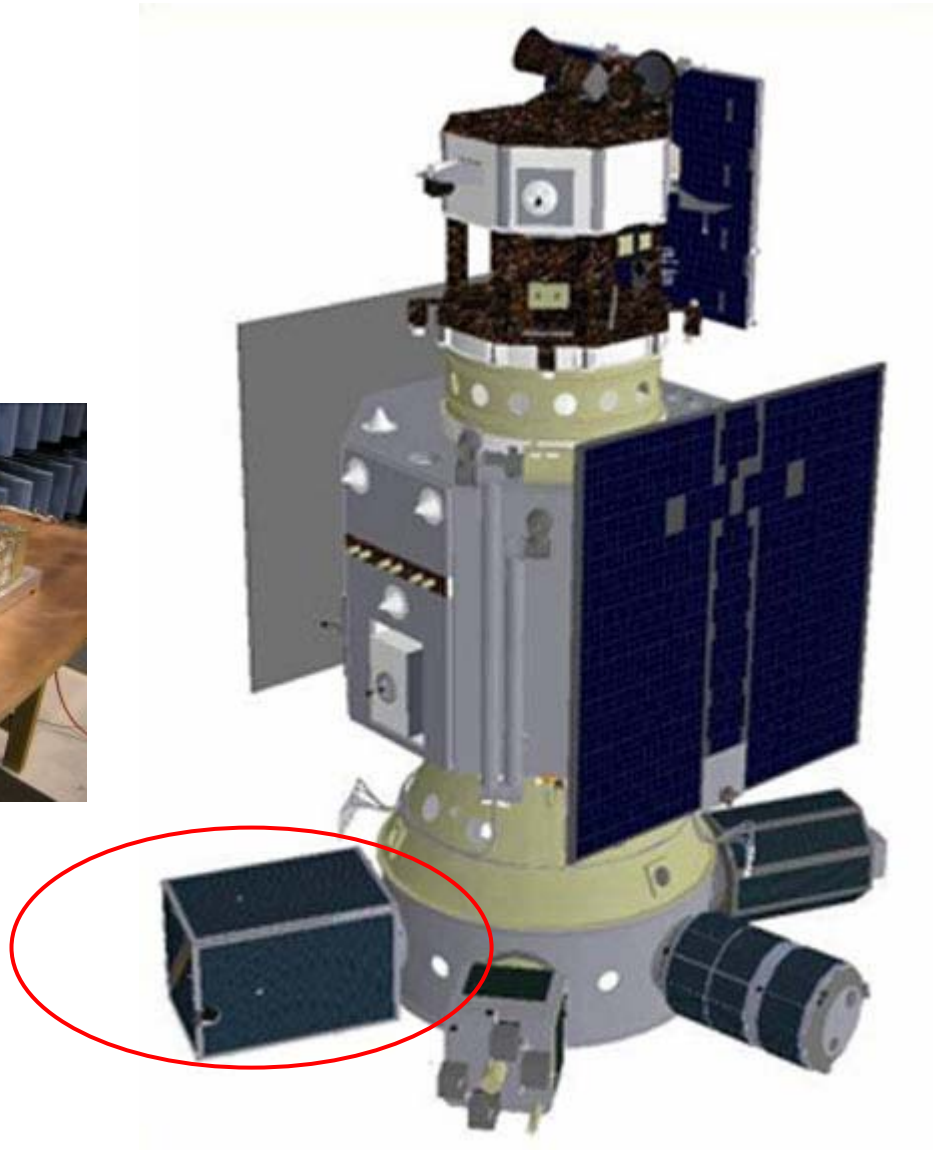
SHIMMER mounted at the mid-deck window
(STS112 in Oct. 2002)

Monolithic SHS for SHIMMER on STPSat-1

The SHIMMER instrument and STPSat-1



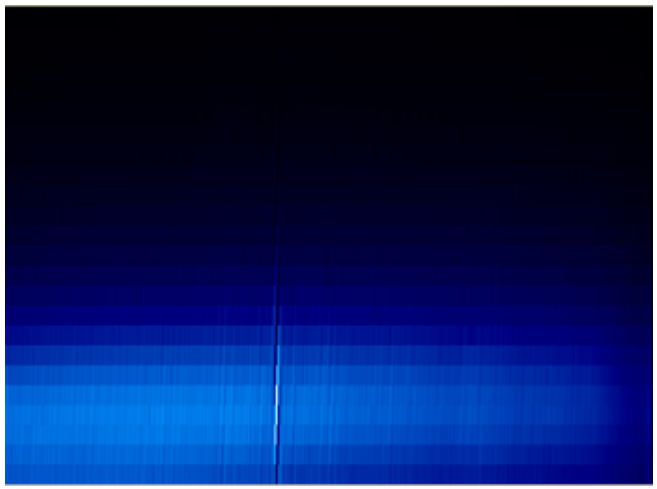




The SHIMMER Launch March 8, 2007

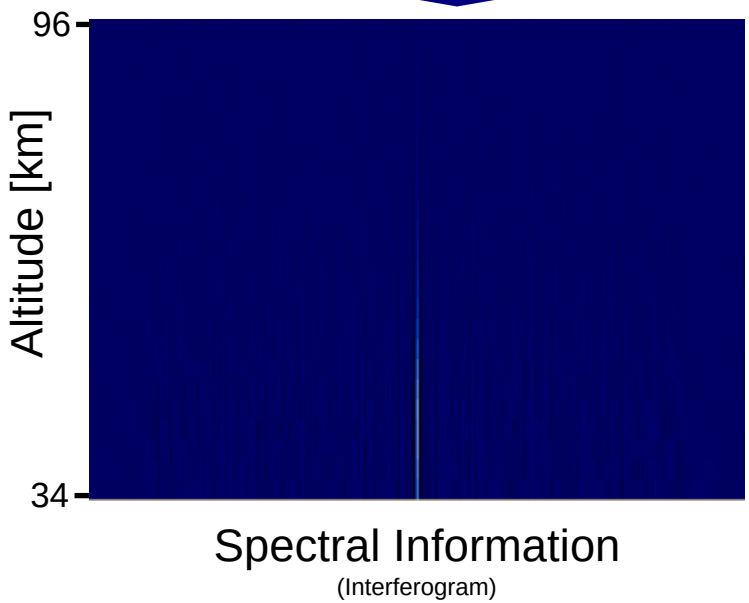
Preliminary Look at Fist Light Data

Raw SHIMMER CCD Data

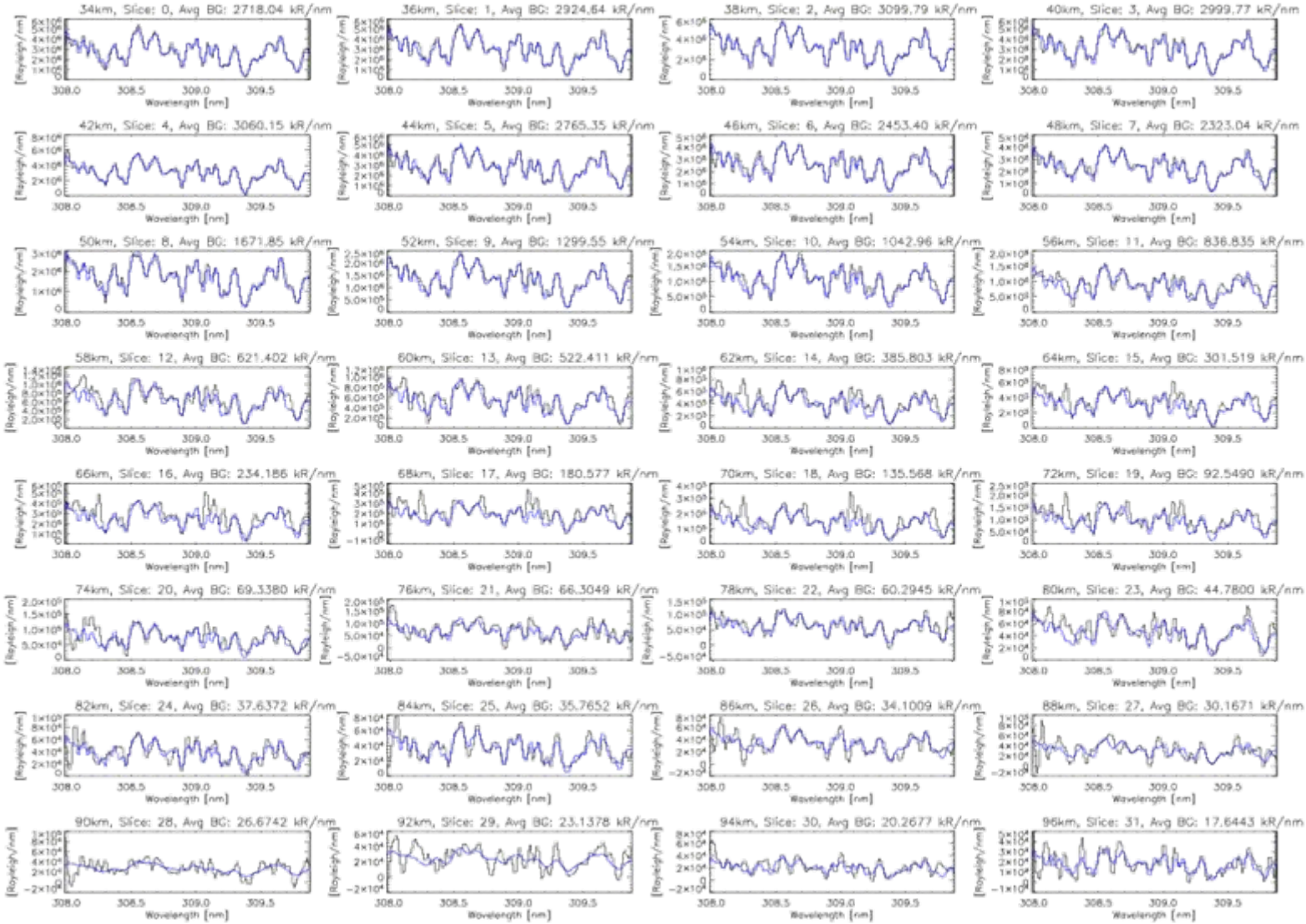


Average of 10 exposures with 6s integration time each.

Bias & Dark Field Correction
Flat Field Correction
Phase Correction
Spike Correction

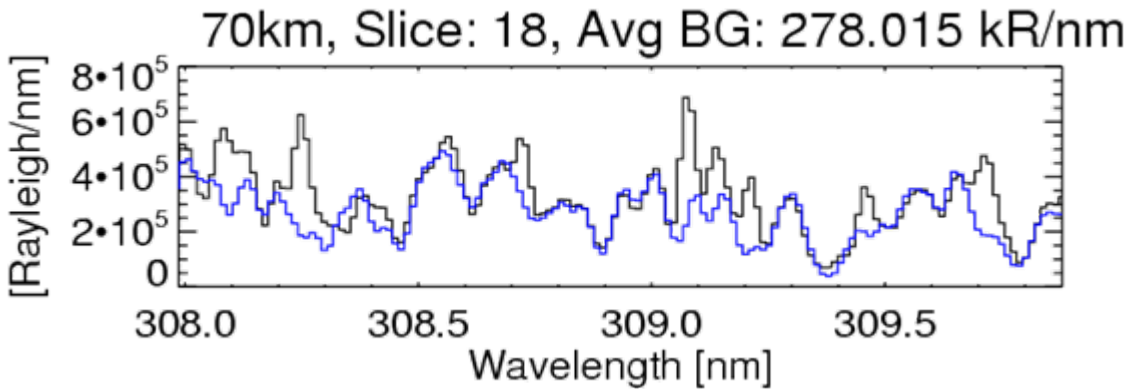


Preliminary First Light Spectra & Solar Background

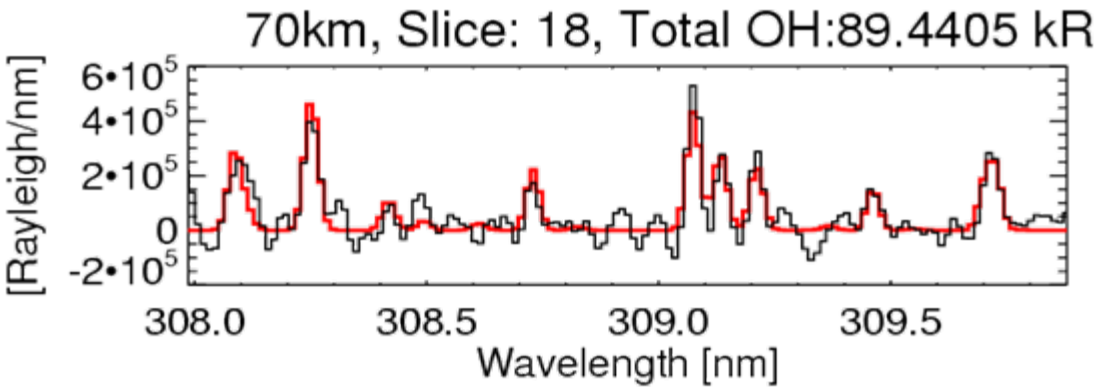


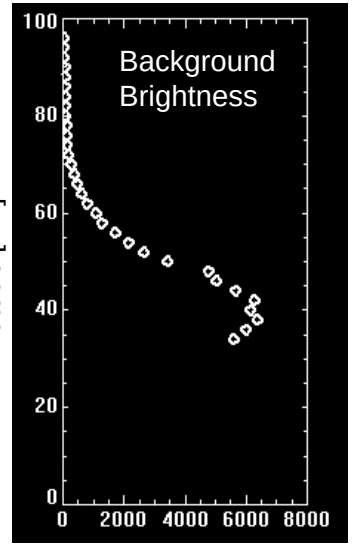
Preliminary Analysis for 70km & Altitude Profiles

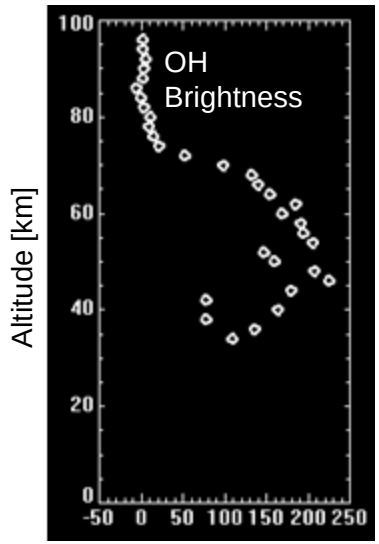
Total Spectrum
Fitted Solar Background



Residual
Fitted OH Emission







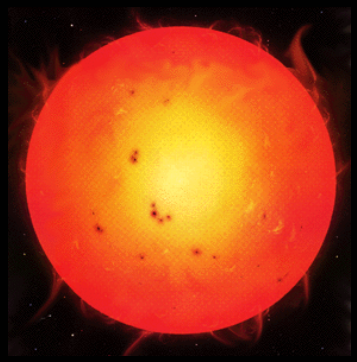
SHIMMER on STPSat-1

...to be continued

National Science Foundation
WHERE DISCOVERIES BEGIN

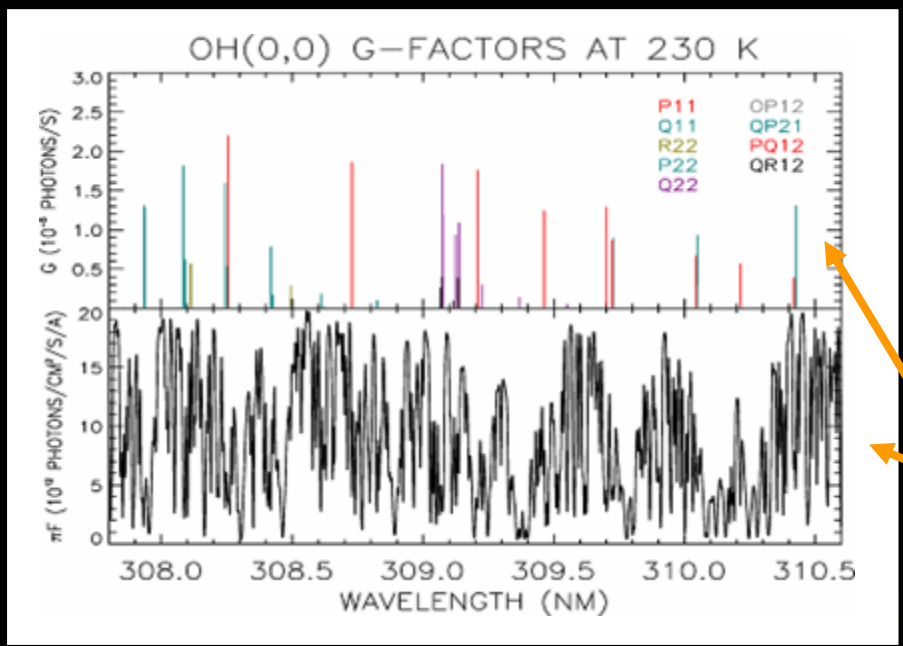
END

SHIMMER Measures OH Resonance Fluorescence



309 nm

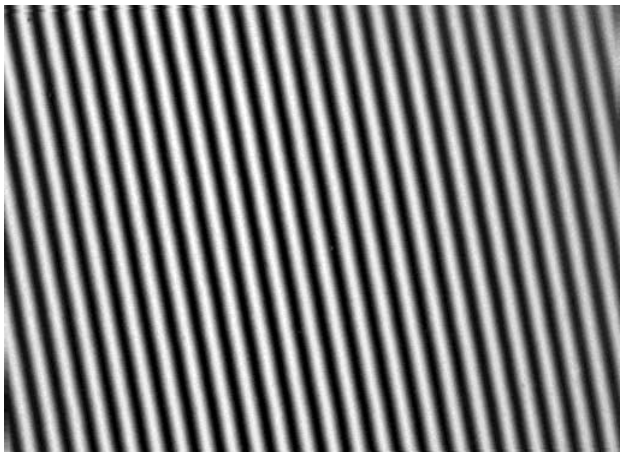
OH

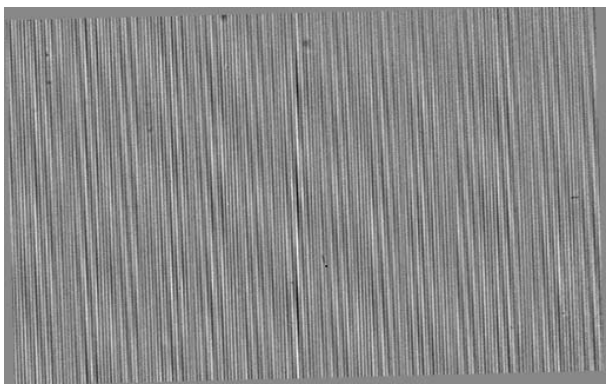


The excitation of each OH rotational line depends on the highly structured solar spectrum.

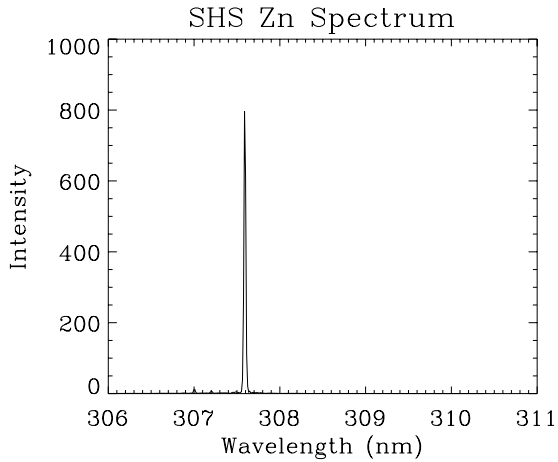
Monolithic Interferometer laboratory tests

Fringes

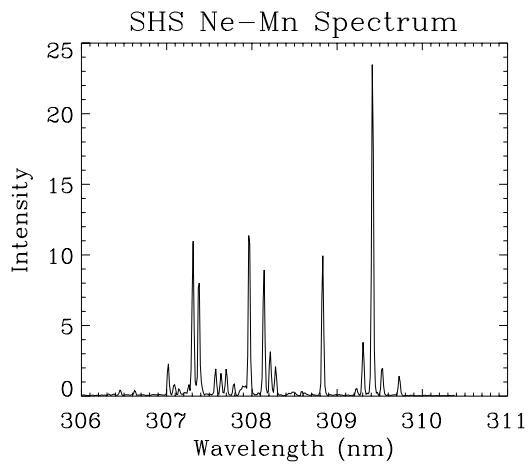




Spectra



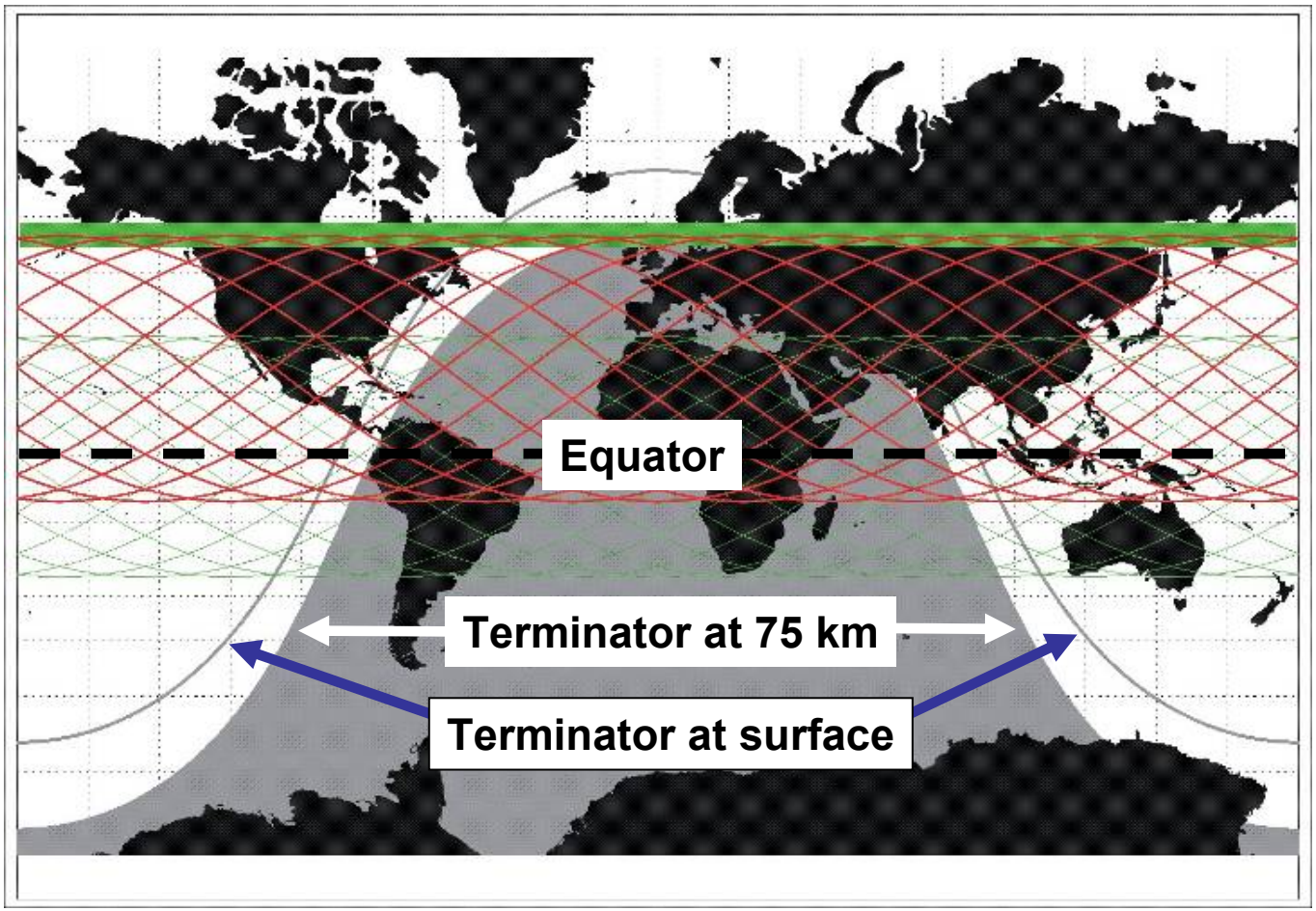
Monochromatic source
Zn pen ray



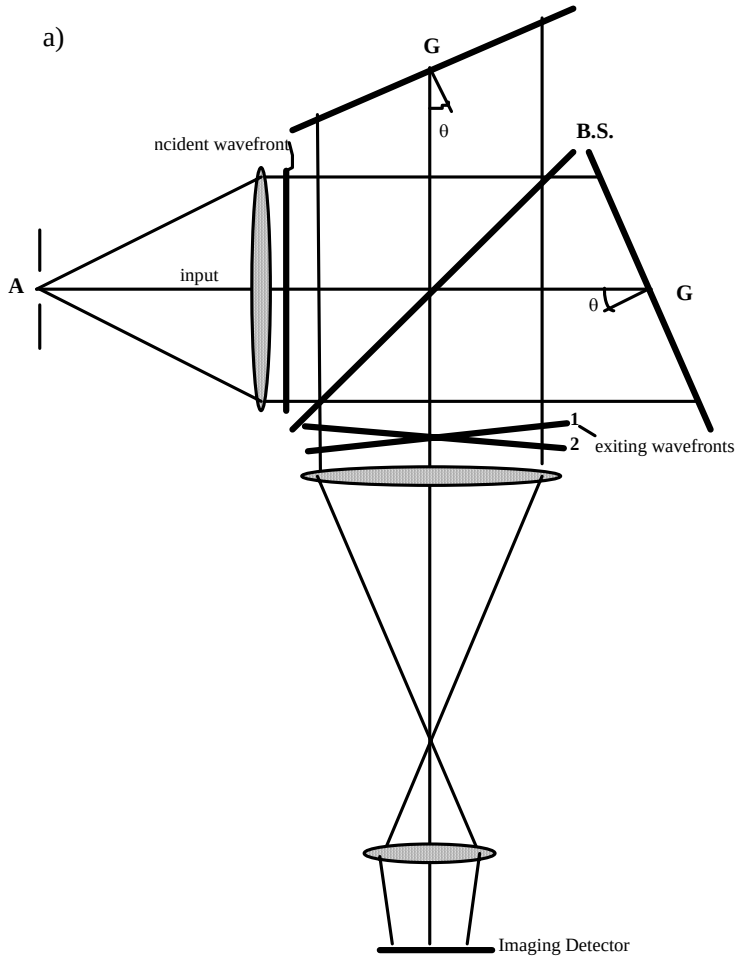
Polychromatic source
Th-Ne hollow cathode

SHIMMER Measures up to ~57° in the Summer HS

Example: Northern Summer



~5% PMC
(Bailey et al. 2007)


a)
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ncident wavefront
A
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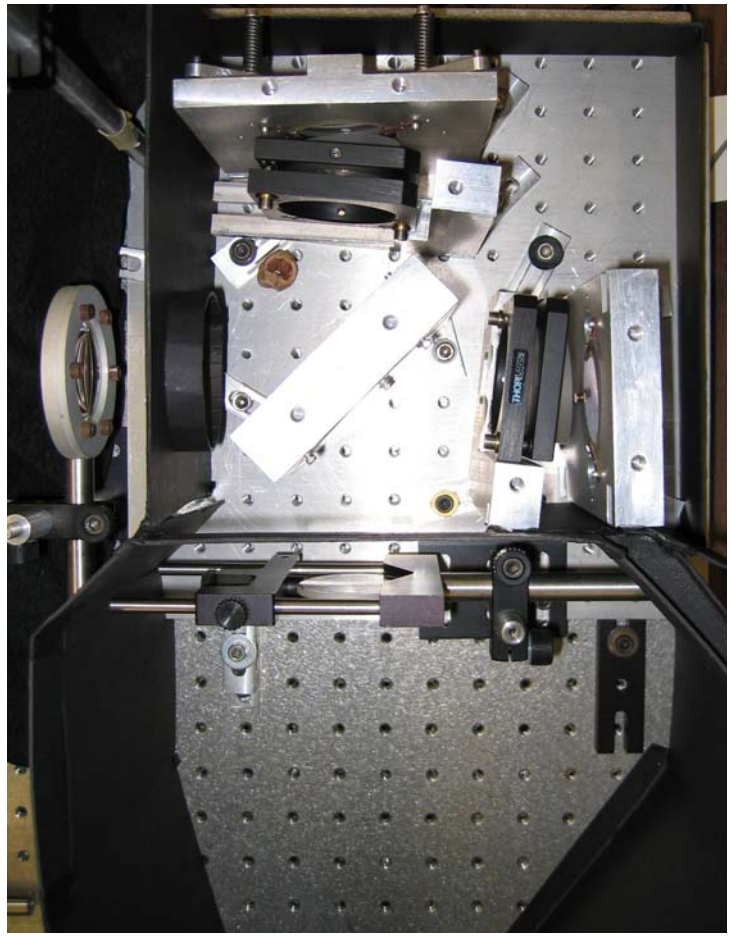
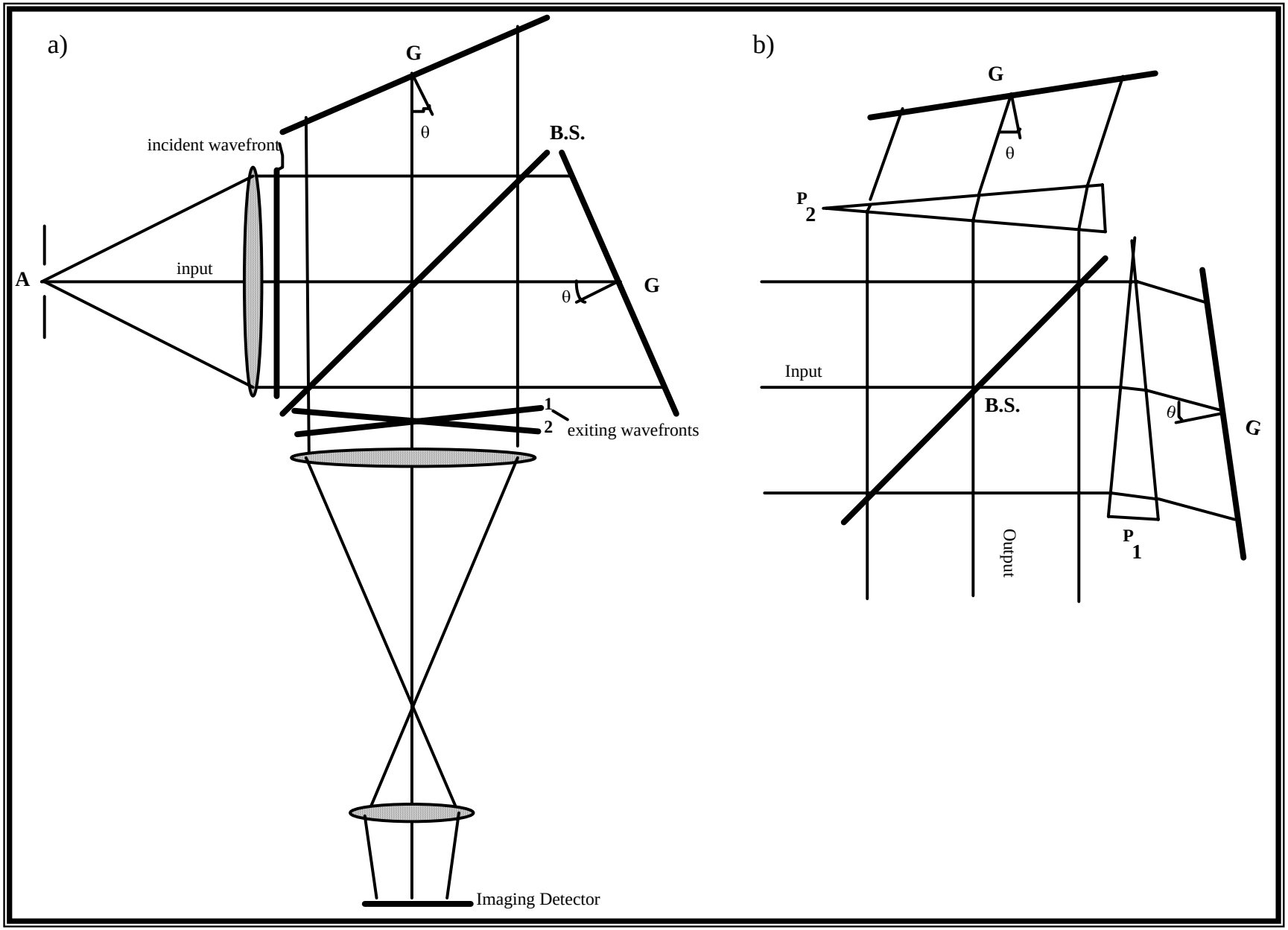
exiting wavefronts
Imaging Detector




a)
G
θ
incident wavefront
B.S.
A
input
θ
G
1
2
exiting wavefronts
Imaging Detector
b)
G
θ
P
2
Input
B.S.
θ
G
Output
P
1

SHIMMER

Spatial Heterodyne IMager of MEsospheric Radicals

Science Motivation:

- OH is an important oxidizing agent in the Earth's atmosphere
- OH resonant scattering at 308nm was measured by MAHRSI
- Photochemical models fail to predict the observed results

Why SHS?:

- Grating instruments meeting science requirements are too large for small satellites
- The field-widened SHS achieves the requirements in a small package without moving parts
- Fabry-Perot efficiencies low at 300nm.

Status:

- A manually tuned SHIMMER flew aboard STS112 in Oct. 2002.
- SHIMMER using the monolithic SHS was launched successfully on March 8, 2007 and is operating well