The SHIMMER Instruments: (An NSF Small Satellite Program Before the Fact) or… How an NSF instrument was backed into the DOD Space Test Program

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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 $\lambda$)
- Can Phase correct post acquisition
- Pixel-limited bandwidth ($N/2)(\lambda / R$)
- Cross-tilt removes $\pm f$ ambiguity
- Instantaneous spectral coverage
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

- Interferometer
- Telescope
- CCD Camera
- Relay Optics
SHIMMER mounted at the mid-deck window
(STS112 in Oct. 2002)
Monolithic SHS for SHIMMER on STPSat-1
The SHIMMER instrument and STPSat-1
Preliminary Look at Fist Light Data

Raw SHIMMER CCD Data

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

Altitude [km]

Average of 10 exposures with 6s integration time each.
Preliminary First Light Spectra & Solar Background
Preliminary Analysis for 70km & Altitude Profiles

70km, Slice: 18, Avg BG: 278.015 kR/nm

70km, Slice: 18, Total OH:89.4405 kR
SHIMMER on STPSat-1

...to be continued
END
SHIMMER Measures OH Resonance Fluorescence

The excitation of each OH rotational line depends on the highly structured solar spectrum.
Monolithic Interferometer laboratory tests

Fringes

Spectra

SHS Zn Spectrum

Shaded area indicates the intensity of light at different wavelengths. For Zn, a single sharp peak is observed at a specific wavelength.

SHS Ne-Mn Spectrum

A broader spectrum is shown for Ne-Mn, indicating multiple peaks at different wavelengths.

Monochromatic source
Zn pen ray

Polychromatic source
Th-Ne hollow cathode
SHIMMER Measures up to ~57° in the Summer HS

Example: Northern Summer

Equator

Terminator at 75 km

Terminator at surface

~5% PMC
(Bailey et al. 2007)
a) Incident wavefronts enter the system at point A. The waves pass through a beam splitter (B.S.) at angle θ. The exiting wavefronts are labeled 1 and 2. The imaging detector is situated at point G, capturing the emerging wavefronts.

b) In the right diagram, the input wavefronts are shown entering the system. The output wavefronts are labeled P1 and P2, emerging at angle θ. The beam splitter (B.S.) is positioned at G, facilitating the separation of the wavefronts for analysis.
SHIMMER
Spatial Heterodyne IMager of Mesospheric Radicals

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Status:
• SHIMMER using the monolithic SHS was launched successfully on March 8, 2007 and is operating well