Optical Airglow Observations at HIPAS

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The heater antenna array is capable of delivering a cumulative power output of 43.7 MW at a zenith angle of up to 36°. With a total of eight crossed dipoles in the array, each dipole spans 94 feet in length and sits 46 feet off the ground.

The effective frequency range is between 2.80 and 2.90 MHz and supports both X and O mode polarizations.

The array is located at HIPAS at latitude: 64° 52’ 22.4” N; longitude: 146° 50’ 12.4”.
Antenna Pattern of the Transmitter Array

Left figure shows the simulated antenna pattern of HIPAS antenna array when pointing along the magnetic field line (204° from geophysical north and 13° from vertical).

The antenna gain is 17.37 dB and the 3 dB beam width is 23.3°.
Second harmonic of the electron cyclotron frequency versus height at HIPAS

Airglow Enhancement
Sporadic E Layer
Electro-jet

HIPAS latitude: 64.873N longitude: 146.837W
Transmitted Frequency Matches $2\omega_{ce}$ and Plasma Frequency

The density profile and the second harmonic versus the height curve intersects at 2.85 MHz—the frequency transmitted on Feb. 5, 2005.

The matching height ranges from 215 km to 260 km. Observations of 630 nm and 557 nm emission were obtained over this range.
HIPAS Optical Measurement Equipment

CCD Camera: Hamamatsu C7190-10 EB-CCD
512x512 12-BIT Resolution
10 μs Minimum Exposure;
-80°C Min. Temp

CCD Camera: Hamamatsu C4742-98-24 ERG
1344x1026 16-BIT Resolution
30 μs Minimum Exposure;
-60°C Min. Temp

Nikon Lens: 24mm/F2.0, 24mm/F2.8

Liquid Mirror: 2.7 M Diameter Aperture

Fresnel Lens: 1.1 M Focusing Lens
First airglow generated by HF radiation at the second electron gyroharmonic directed up the magnetic field line in the polar region

Imaged by C7190-10 EB-CCD with 630 nm filter

Reprocessed airglow data taken on UT March 14, 2002 at HIPAS. The fully developed image size of the airglow is about 10° by 10°.
Detailed Features of Airglow Structure

Airglow developed from tiny locations, which may be
Created by density cavities and plasma irregularities.
Detailed Features of Airglow Structure

Localized hot spots merged into airglow structure of irregular shapes
Detailed Features of Airglow Structure

Optical Image at 630 nm on UT 2002 March 14

Fully developed airglow structures extended to about 10° in size, roughly comparable to the 11.6° of the radiation beam half width.
Beam Tilting on 14 Feb. 2002 at 630nm

The figure shows when the HF beam was tilted away from the field line (Beam 13,204) how the airglow position was affected. We tilted the HF 10° away from field line. However, the center of the beam tilted less than 3°. This demonstrates the field line dependence.

<table>
<thead>
<tr>
<th>Beam Code</th>
<th>Gain (dBi)</th>
<th>Airglow tilted angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam 13,204</td>
<td>15.69</td>
<td>0.32°</td>
</tr>
<tr>
<td>Beam 13,214</td>
<td>17.28</td>
<td>1.20°</td>
</tr>
<tr>
<td>Beam 23,204</td>
<td>14.6</td>
<td>2.70°</td>
</tr>
<tr>
<td>Beam 13,194</td>
<td>17.3</td>
<td>1.40°</td>
</tr>
</tbody>
</table>
Recent Optical Airglow Observations
2005 Feb 05 UT

Left, the figure shows the average of the signal intensity over all the pixels in one image as a function of time. We used Hamamatsu C7190-10 EB-CCD camera with a 630 nm line filter to get these images. The exposure time for each image was 8 seconds. This demonstrates that the 630 nm emission needs around 100 seconds to build up and around one minute to fade away.
Airglow signal was detected by Fresnel lens system, which includes a 36 inch diameter lens, 630 nm filter, and a photomultiplier tube. HF radiation was transmitted one minute on and one minute off (left), and 30 seconds on and 30 seconds off (right).
The HIPAS airglow was also detected by Todd Pedersen at HAARP at 630 nm (red) and 557.7 nm (green). Before 3:40 AM UT, the HF radiated two minutes on and two minutes off. From 3:40 AM UT the HF schedule was one minute on and one minute off. After 3:56 AM UT the HF schedule was changed to 30 seconds on and 30 seconds off.
In this experiment, the transmitters were turned on and off for 30 seconds. The Hamamatsu C7190-10 EB-CCD with a 577 nm line filter was used. The exposure time for the left figure was 3 seconds. For the right figure it was 1 second.
Summary of Observations

Enhanced airglow was generated near the double resonance that matches the plasma resonance and the second harmonic electron cyclotron frequency first on **UT March 14 2002** and following up on Feb 4-6, 2005.

Optimal emission was observed when the HF radiation was directed up the magnetic field. The maximum emission displaced away from the beam center over 7° toward the magnetic zenith when the HF radiation was directed 10° away from the magnetic zenith.

Airglow exhibits localized regions of bright spots which may be initiated by cavitons and plasma irregularities.

The total developed airglow size is about 5-10° depending on the beaming angle with respect to the magnetic zenith. The range for the airglow is about 215km to 260km.

The electron acceleration and evolution time appeared to be shorter than the detector exposure times (1 second) used for the imaging.