Motivation/Objectives
Recent models for ion heating in the fast solar wind region of the Sun predict the heating is due to MHD turbulence driven by counter propagating, low frequency Alfvén waves [1]. Experiments to test this theory will be conducted in the West Virginia University HELIX (cylindrical Millimeter device in helicon plasma) facility. HELIX is on the order of 100 cm-3 with ion temperatures of about 0.3 eV. To create counter propagating Alfvén waves one of two techniques will be employed. We will first attempt to launch Alfvén waves from the helicon source region and generate a reflection due to an Alfvén-speed gradient. The HELIX device has an Alfvén-speed profile unique in the solar corona, a short region of increased Alfvén speed followed by a rapid decrease in speed as the magnetic field expands. Should the first method prove to be unfeasible, two waves will be launched at each other from different antennas. This method has the added advantage of allowing the absolute intensities of the counter propagating waves to be valued. Temperature of helicon ions will be measured using a RF compensated energy analyzer. We will present information on the experimental apparatus as well as preliminary data.


Experimental Apparatus
Of particular interest for this experiment is the similarity of the magnetic field gradient between the sun and HELIX/LEIA resulting in a gradient in Alfvén speed. The reflection of the Alfvén-in waves is expected to occur at this gradient. Note that the magnitudes are identical and the negative signs is as a result of coordinate selection.

Suitability of HELIX for coronal simulation (in He)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>LPD</th>
<th>ALPSPI</th>
<th>HELIX</th>
<th>Coronal Holes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ω (kHz)</td>
<td>2.2</td>
<td>10</td>
<td>50</td>
<td>500</td>
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<tr>
<td>T (eV)</td>
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<td>8</td>
<td>8</td>
<td>8</td>
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<tr>
<td>B (G)</td>
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<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
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<tr>
<td>Ωci (kHz)</td>
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<td>293</td>
<td>293</td>
<td>293</td>
</tr>
<tr>
<td>Vci (cm/s)</td>
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<td>0.5</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>kΩci (cm)</td>
<td>1</td>
<td>0.5</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>kΩci (ppm)</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Alfvén waves in HELIX
The dispersion relation for shear Alfvén waves in the kinetic regime (Vw/Vci) is given by

\[ \frac{\omega}{\Omega_{ci}} = \sqrt{1 - \frac{\Omega_{ci}^2}{k^2 V_{ci}^2}} \]

To efficiently launch and detect electromagnetic waves at such low frequencies (~30 kHz) requires an efficient coupling of the rf source to an antenna and a high gain receiver.

Wave launching apparatus
Following the approach of Hanna and Watts [2001], a small coil wound on a ferrite is inserted into the plasma via a passively water cooled probe. Currently, the probe housing is bare stainless steel. Future versions will be coated with a layer of insulating alumina.

The 0.25” diameter, 1.025 mH coil is coupled to a 1 kW, 25-125 kHz generator. Wave detection is accomplished by a passive waveguide detector. Observed phase shift as a function of downstream frequency changes between the sun and HELIX/LEIA by 1.5 radians. Note that the observed phase shift increases with frequency. This will be of particular interest for this experiment as it is the similarity of the magnetic field gradient between the sun and HELIX/LEIA resulting in a gradient in Alfvén speed. The reflection of the Alfvén-in waves is expected to occur at this gradient. Note that the magnitudes are identical and the negative signs is as a result of coordinate selection.

Bandpass filtered amplifier design
5 narrow bandpass, single input, three stage, active filters built for wave frequencies of 20, 40, 60, and 100 kHz. Filters will be used for detection of heavily damped shear Alfvén in waves in both helium and argon plasmas.

Sub-cyclotron frequency waves observed 1 m downstream of in-situ antenna in argon plasmas

Wave dispersion consistent with Alfvén wave excitation
To test the transmitting and receiving coils, 200 kHz waves were launched and detected 30.5 downstream. For source parameters yielding an ion-cyclotron frequency of 14.5 kHz, the most likely electromagnetic wave to be launched is a whistler wave governed by the dispersion relation:

\[ k = \frac{\omega}{V_{ci}} \geq -1 \]

Phase shift as a function of increasing plasma density inconsistent with whistler wave propagation.

Sub-cyclotronwavenumber versus RF power (plasma density)
One would expect to see the phase shift increase with increasing RF power (density). The observed phase shift dependence on RF power is yet to be understood and may indicate some change in the characteristics of the excited wave for different plasma parameters, e.g. variations in excited k.

Comparison with previous experiments
The ion-cyclotron resonance in the shear Alfvén wave dispersion has been observed in previous helicon plasma experiments [Figure from Wu & Hanna, Phys. Plasmas, Bl. 135, 2004]. In the helicon plasma case, the ion-cyclotron frequency is 270 kHz and a similar increase in phase difference (normalized) is seen near cyclotron resonance.