HELICONS, HISTORY, HIGH TECHNOLOGY AND HELIACS

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Being a brief introduction to helicon/whistler waves, their discovery, experimental and theoretical investigation, both terrestrial and planetary, use of wave trapped electrons to increase the ionization rate and eventual development to heat heliacs and in the micro-electronics industry. A controversy will be unveiled.

DISCOVERY

The first report in a scientific journal of these whistling tones was given in 1919 by Barkhausen in a report of whistling tones from the earth heard on telephone lines at the war front. They were descending tones from about 1 kHertz which lasted up to a second and sometimes were so loud that other normal telegraphic communication could not be distinguished. The soldiers christened the phenomenon "the grenades fly", making a sound like "peou".
Initially, it was suspected that these were communications from extra-terrestrial being and newspapers indulged in some rather fantastic speculation involving messages from Mars.

DISPERSION

For infinite plane waves the inclusion of a magnetic field opens a propagation window below the electron cyclotron frequency which allows whistler or helicon waves to propagate.If electron inertia is ignored then the wave dispersion is dominated by the Hall term (j x B) and the wave is simply electromagnetic.Including the electron inertia via the term dj/dt in Ohm's law brings a severe anisotropy to the dispersion and the wave acquires electrostatic properties (E // k).

$$N^2 = 1 - \frac{\omega_{pe}^2}{\omega\left(\omega - \omega_{ce}\cos\theta\right)}$$

This is the Appleton/Hartree dispersion relation derived about 1935 later simplified by Booker.

TERRESTRIAL EXPERIMENTS

"ZETA" experiments	1960
Name Helicon coined by Aigrain	1960
KMT and Legendy developed theory	1964
Experiments at Culham in rf plasma	1965
Flinders test waves	1967
Flinders ionising helicon	1968
Lisitano's coil	1968
Oechsner's cavity resonances	1970
Nothing happens	1970's
ANU 5 cm. and 20 cm. experiments	1981
Pulsed etch experiments	1984
Nagoya III ionises plasma	1986

DAMPING MECHANISMS
Operate for electron densities < 1013 cm-3 and neutral pressures < low milliTorr.
Collisionless damping $\omega - kv_z = n\omega_{ce}$

n = 0 Landau and wave particle trapping
n = 1 Cyclotron damping
n = -1 Anomalous cyclotron (cyclotron maser)

CHRONOLOGY

Landau rigorous solution of Vlasov	1946
Dawson physical explanation	1959
Shafranov and Dolgopolov	1958/63
recently F. F. Chen	late 1980's

HIGH TECHNOLOGY

Henry, Laure, Bouchoule, Orleans	1983
Boswell and Henry 1984	1984
ANU patent	1985
Etching experiments ANU and Lucas	1989
UCLA patent	1989

about 350 helicon publications in past 10 years

many companies have been involved
ANU: Alcatel, Lucas Labs, Ericsson, Javac, LAM Research, Nissin Electric, Enya Systems
UCLA: PMT, Cannon, Anelva.....?

PROCESSING REQUIREMENTS
High current density about 10 $mAcm^{-2}$
Low independent bias about 50 Volts.
Uniform over 300 mm.
Processing speed 0.1 to 1 μmetre per minute
Low down time
Process stable over weeks
Minimum dust generated

HELICONS IN THE H1 HELIAC
Fusion stability experiment (ballooning modes)
Helicon antenna single saddle field
7 MHz and 100 kWatts
Argon @ 1 - 5 x 10^{-5} Torr

PROBLEMS
What is heating the ions
Why are electrons cooler in the centre

A CONTROVERSY
How do the resonance cones contribute to the radial structure?
Why is the dispersion infinite plane wave parallel to Bo?
Where are the T=G modes?