A TWT-Upgrade to study wave-particle interactions

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Widely used as HF wave amplifiers for industrial applications, Traveling Wave Tubes (TWT) are also used to mimic and carefully study wave-particle interaction in a plasma [1-3]. We describe a recently built upgrade of a TWT whose slow wave structure consists of a 4 m long helix, with 3.4 cm diameter and 1 mm pitch, made of a 0.6 mm diameter Be-Cu wire wrapped in an insulating tape. The helix is inserted in a glass tube evacuated by two ion pumps on both ends. At one end, an electron gun made of a triode produces an electron beam propagating along the axis of the helix and radially confined by a constant axial magnetic field. Four movable probes capacitively coupled to the helix through the glass tube are used to launch and monitor a spectrum of waves generated by an arbitrary waveform generator at a few tens of Mhz. At the other end of the helix, a trochoidal analyzer allows to reconstruct the electron distribution functions of the beam after its self-consistent interaction with the waves. Linear properties of this new device will be reported.

Principle of the experiment

The 1D beam-plasma system is a paradigm to study self-consistent wave-particle interaction in plasma turbulence. The bulk plasma acts as a linear dielectric to support the wave propagation and can be advantageously replaced by a slow wave structure, such as the helix in a Traveling Wave Tube (TWT). One is left with studying the essentially 1D interaction of the beam, propagating close to the axis of the helix since confined by a strong magnetic field (500G), with the waves, propagating along the structure and which, close to the axis, mainly consist in a longitudinal electric field.

Up-grade of the experimental set-up

We had to face a forced up-grade of our TWT since, as shown in Fig.1 (left), the glass tube was broken. In the previous design of the TWT the helix was held inside the evacuated glass tube by three alumina rods visible on the figure. This resulted in a rather fragile system. In the TWT-upgrade, we opted for a much more mechanically robust design: the 4 m long helix, with 3.4 cm diameter and 1 mm pitch, made of a 0.6 mm diameter Be-Cu wire is wrapped in an insulating tape and then inserted into the glass tube, as shown in Fig.1 (right). As in the previous TWT, absorbing tapes are used at both ends of the helix to reduce electromagnetic wave reflection.

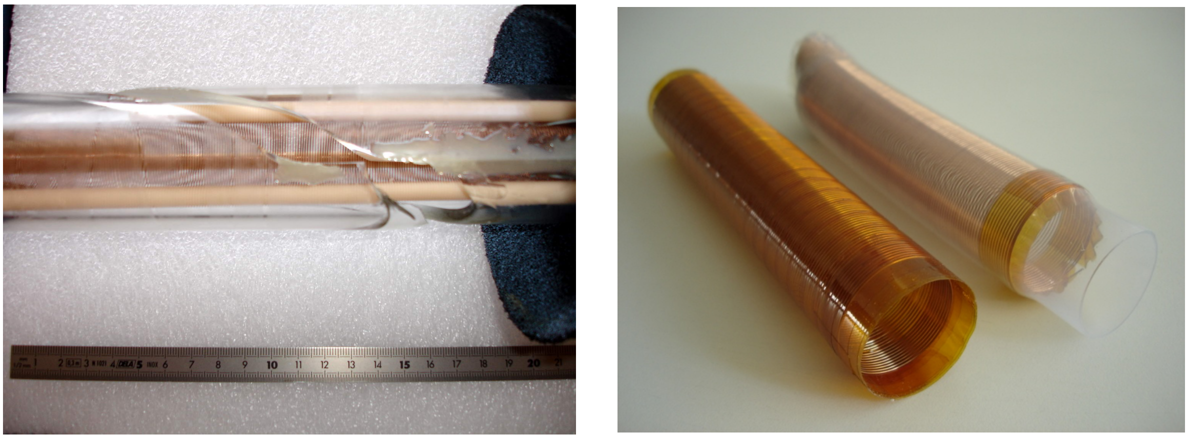

Fig. 1 : left) view of the broken helix, supported by three alumina rods in the glass tube, right) helix glued inside tape and inserted inside the glass tube.

The evacuated glass tube is set on the axis of a slanted wave-guide to shield electromagnetically the TWT. Four probes are capacitively coupled to the helix through the glass tube. In the TWT-upgrade, great care has been given to improve the precision and repeatability of the probes position as shown in Fig.2. Probes can be used to launch or receive a spectrum of waves generated by an arbitrary waveform generator, which allows to control the frequency (between 10 and 80 MHz), amplitude and phase of each wave.

As in the previous TWT, at one end, a triod with a pierced anode (3mm diameter) is used as an electron gun (10-100 eV) and, at the other end, a trochoidal analyzer allows to measure the electron energy distribution function after the beam has interacted with the waves.

Experimental results

Since, in the TWT-upgrade, the helix is much closer to the probes than in the previous version, the measured signal is larger but much more sensitive to the distance between probe and helix. Great care needs to be given to measure the coupling coefficient between each probe and the helix at any given axial position.

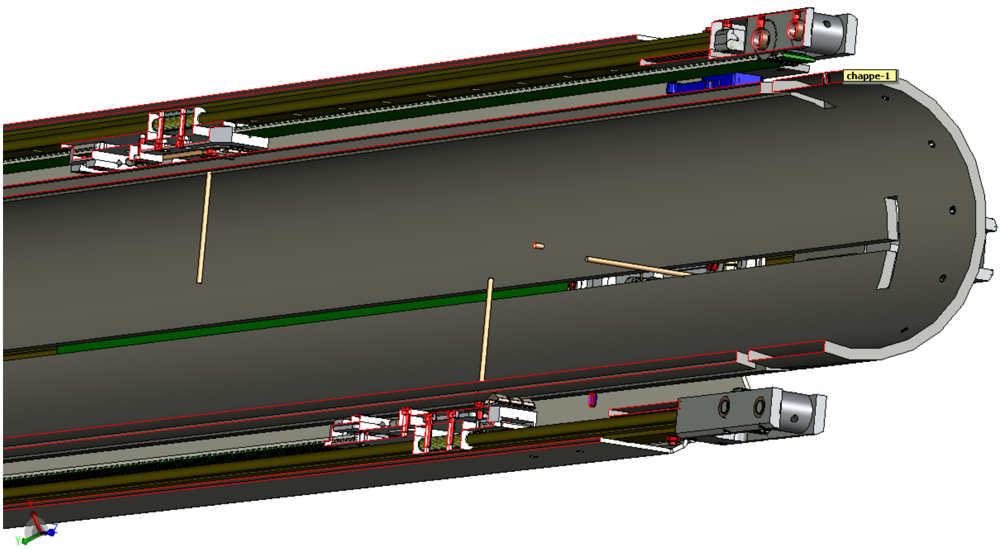

Fig. 2 : Movable probes on their trails (inside precision rail)
positioned by PU timing belts inside slanted wave-guide

The points in Fig.3 show the dispersion relation as measured using an interferometer method, with one probe as an emitter at a given frequency and another probe as a receiver. An excellent agreement is obtained with the the theoretical prediction of a sheet model.

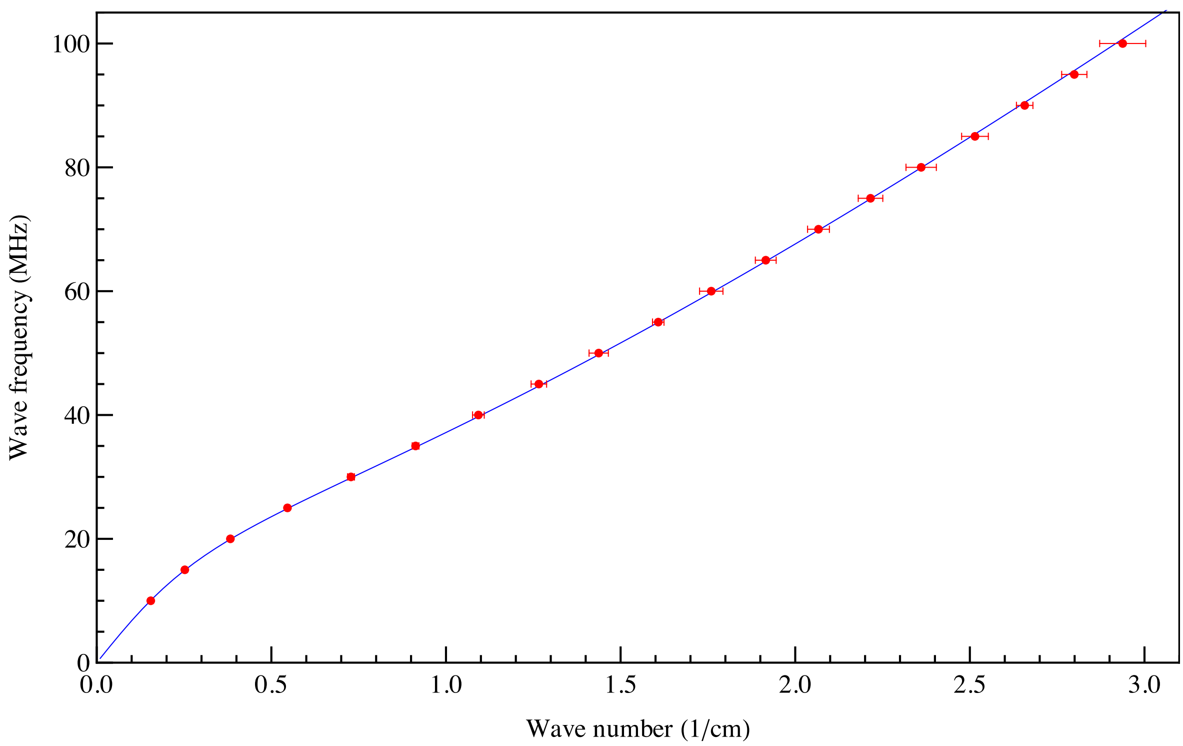

Fig. 3 : Measured and theoretically predicted dispersion relation of the TWT-upgrade.

Perspectives

In TWT-upgrade, we plan to study the synergy between the chaotic behavior observed with a low intensity test beam [3] and the self-consistent effects leading to wave amplification [1] when increasing the cold beam intensity.

TWT-upgrade will serve to bench mark industry oriented codes [4] .

We also plan to launch packets of electrons [5] with a well defined phase with respect to a wave to further explore the electrons phase space.

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