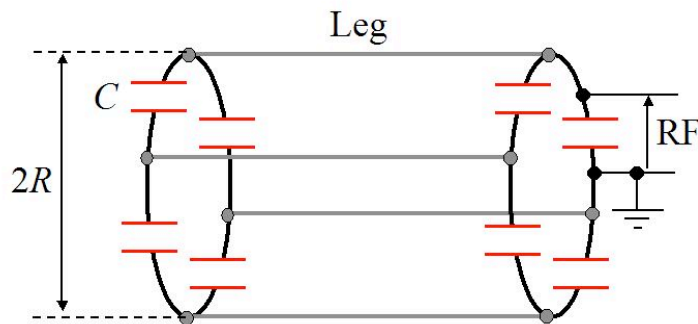


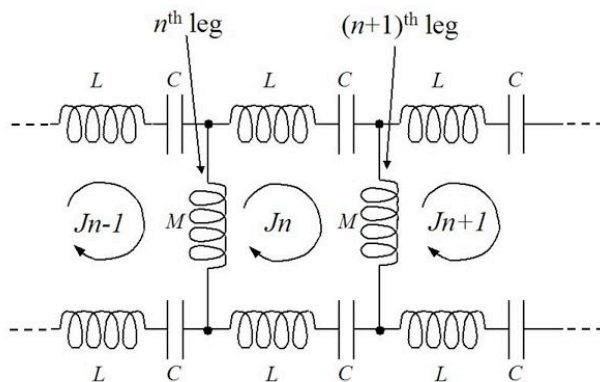
### *Helyssen cylindrical antenna*

Let's now have a look to Helyssen cylindrical antenna. It is basically composed of  $N$  legs regularly spaced around the  $z$  axis. At both ends, each leg is connected to its two closest neighbours by means of capacitors  $C$ . A four leg straight antenna is shown on Figure 7. The number of legs  $N$  (at least equal to 2) could theoretically be as large as desired and is only limited by size considerations.



**Figure 7: Representation of a 4 leg straight Helyssen antenna**

By considering the legs to act essentially as inductive elements the equivalent electrical circuit of this structure corresponds to the one shown on Figure 8.



**Figure 8: equivalent circuit of a portion of Helyssen antenna**

It is clear that this constitutes a resonant circuit. As a matter of fact a  $N$ -leg antenna will present  $N/2$  resonant frequencies. The striking point is that each resonant frequency corresponds to a given  $m$  sinusoidal azimuthal current distribution within the legs. Figure 9 shows the current distributions measured on a 16-leg antenna for the 4 first resonant modes. Hence it appears that we have a structure that fits very well the azimuthal dependence of helicon modes.

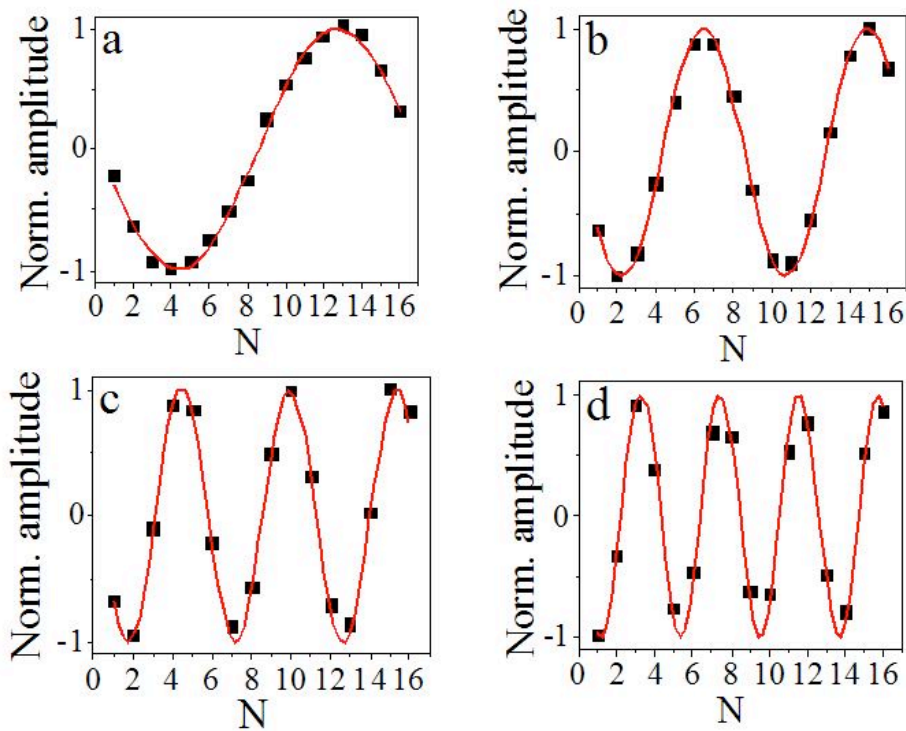


Figure 9: Measurements (dots) of the current distributions in a 16 leg Helyssen antenna for the 4 first resonant frequencies. (a) :  $m=1$  ; (b) :  $m=2$  ; (c) :  $m=3$  ; (d) :  $m=4$ .

As a consequence of this very good fitting, Helyssen antenna allows to control very well the helicon mode to be excited. This point has been demonstrated with a 16 leg straight antenna and is illustrated on the following figures. These show the comparison between the calculated energy deposition in the plasma for modes  $m=1,2,3$ , on the basis of fundamental helicons theory, and CCD (charge coupled camera) images of the discharges obtained with a straight Helyssen antenna for the resonant frequencies corresponding to these modes  $m=1,2,3$ . The correspondence between theoretical and experimental results is quite impressive.

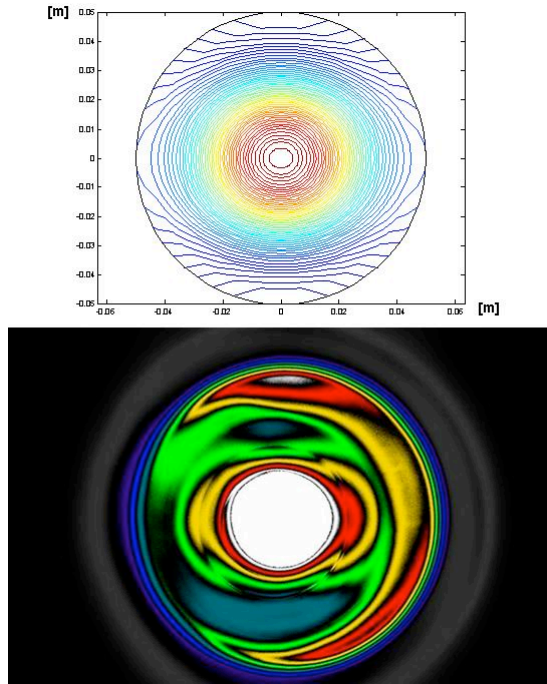


Figure 10: Comparison between calculated energy deposition (up) and CCD image of plasma emission (axial view) for a  $m=1$  mode (argon discharge, RF power : 300 W at 13.56 MHz, pressure :  $10^{-2}$  mb).

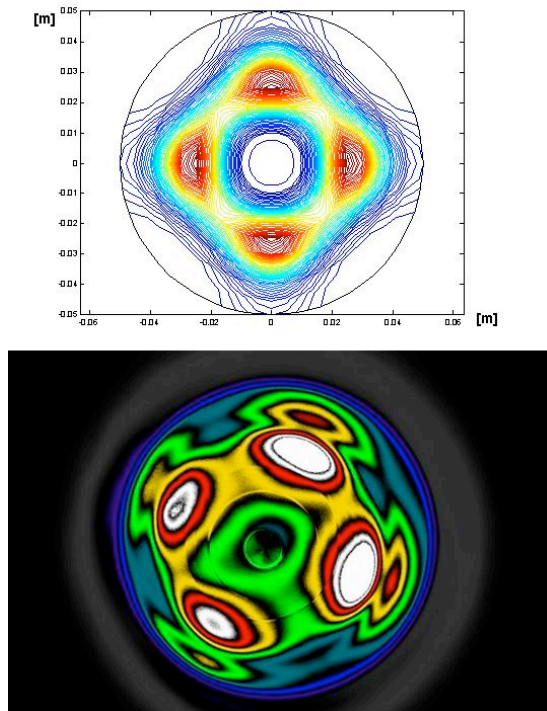
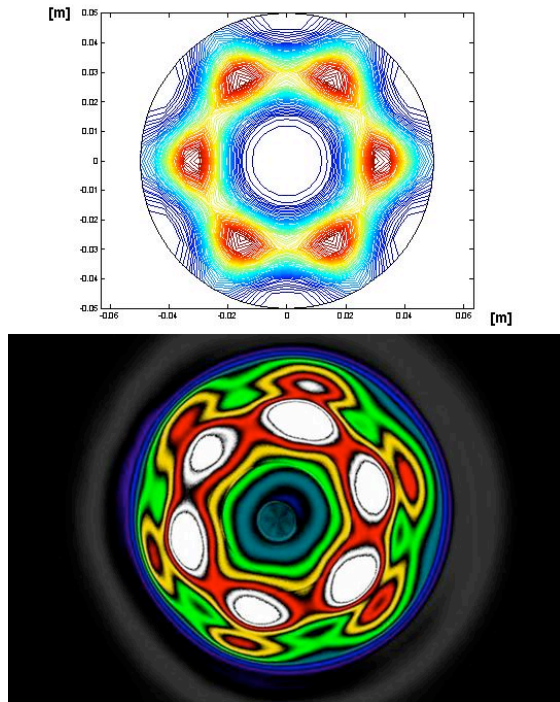
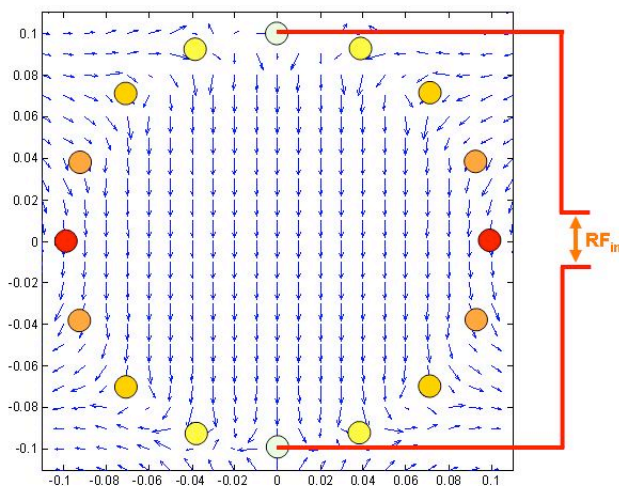


Figure 11: Comparison between calculated energy deposition (up) and CCD image of plasma emission (axial view) for a  $m=2$  mode (argon discharge, RF power : 300 W at 10.75 MHz, pressure:  $10^{-2}$  mb)



**Figure 12: Comparison between calculated energy deposition (up) and CCD image of plasma emission (axial view) for a  $m=3$  mode (argon discharge, RF power : 300 W at 8.82 MHz, pressure :  $10^{-2}$  mb)**

Furthermore, the circular polarisation of the wave field is easily obtained with the Helyssen antenna by mean of quadratic excitation. To illustrate this point we consider an antenna with a  $m=1$  sinusoidal current distribution, as shown on figure 9a. Figure 13 shows the RF magnetic field generated by this current distribution. The RF field appears to be very uniform in the body of the coil and is linearly polarized



**Figure 13: Magnetic field generated by a single  $m=1$  current distribution.**

Now let's have a look to the configuration shown in Figure 14. Here the antenna is fed by two decoupled RF power sources, and the injection points for the two generators are spatially

shifted by  $90^\circ$  azimuthally. Each RF injection will produce its own sinusoidal current distribution, and then the total RF field is a superposition of the two perpendicular RF fields generated by each source. Furthermore, if the temporal relative phase between the two RF sources is fixed to  $90^\circ$ , the resulting field will be constant in amplitude but will rotate at frequency  $\omega$ , which corresponds to the circular polarization.

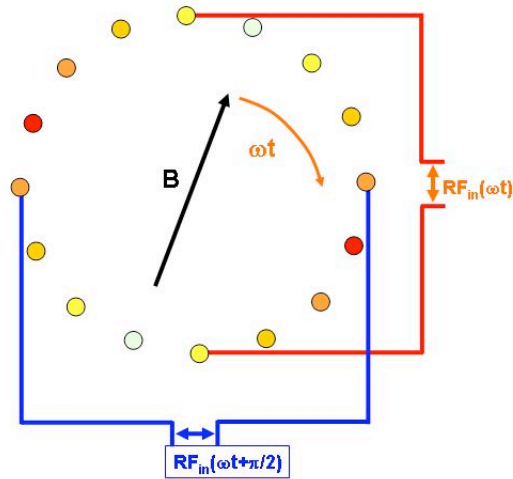


Figure 14: Quadratic feeding of Helyssen antenna to obtain rotating fields.

To resume, the Helyssen cylindrical antenna allows the generation of circularly polarized RF fields with the desired  $2\pi/m$  azimuthal sinusoidal dependence and, if twisted, with a chosen  $k_z$  and sign for  $m$ . It is then an almost perfect device to play with helicon waves.