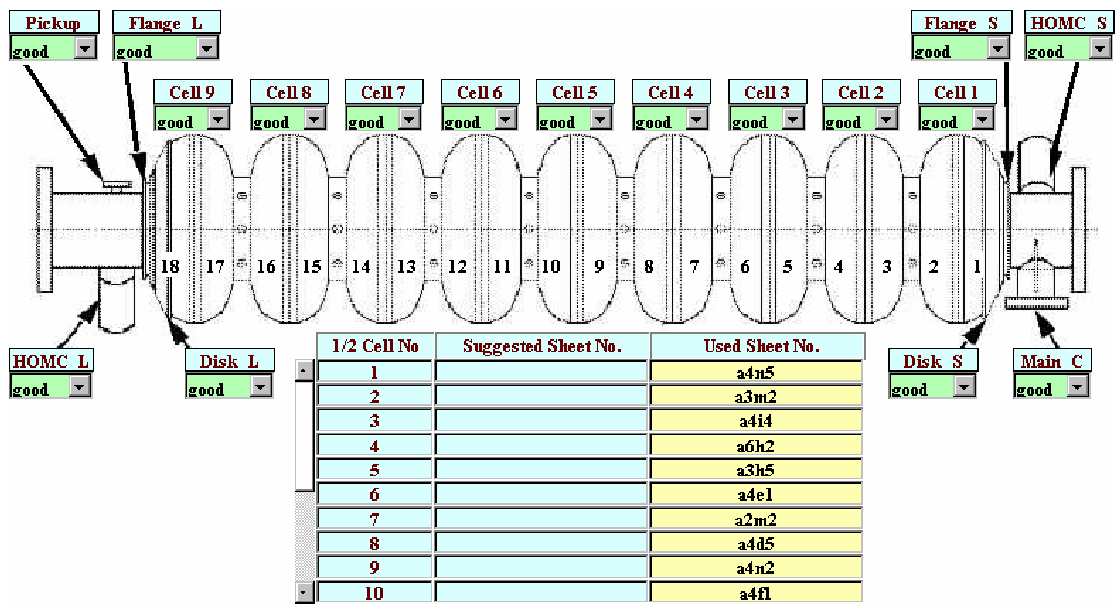
Measurement of electrical axis of XFEL cavities

Guennadi Kreps, Anton Labanc
DESY, MHF-SL

TESLA Collaboration Meeting at DESY Zeuthen, 21st-23rd January 2004

Geometrical axis

- A geometrical axis of 9 cells TESLA cavity is the line between the centres of two reference rings



- Equators and irises of cells are not ideal circles and have deviation from circle +/- 0.15 mm. The second type of the cavity deformation is the “banana” shape if the centre of each cell has the deflection from the axis of the cavity. We adjust each cell to axis with the tolerance 0.4 mm by the mechanical tuning of the cavity. An alignment of the cavity in the module is optimised to make the minimal average deviation of cells to the beam.

Electrical axis

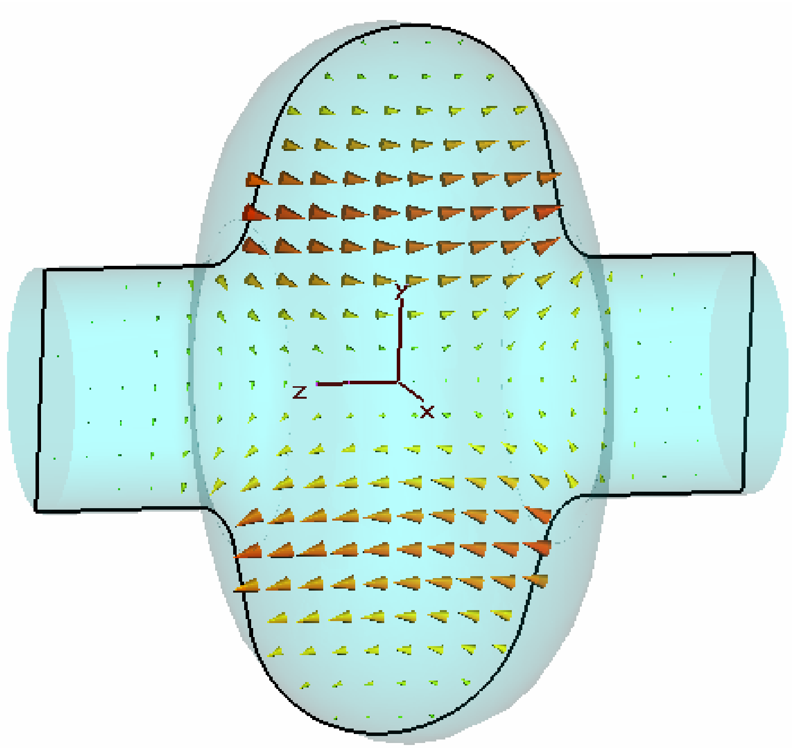
- Each mode in the cylindrical coordinates has an axis of electrical field symmetry - an electrical axis. In general, they are different for different modes. Only in an ideal cavity the geometrical and all electrical axes are identical.

- The inclination electrical axis causes transversal interaction of beam with acceleration mode (TM 010) and the displacement of electrical axis causes a kick to the beam from dipole modes.

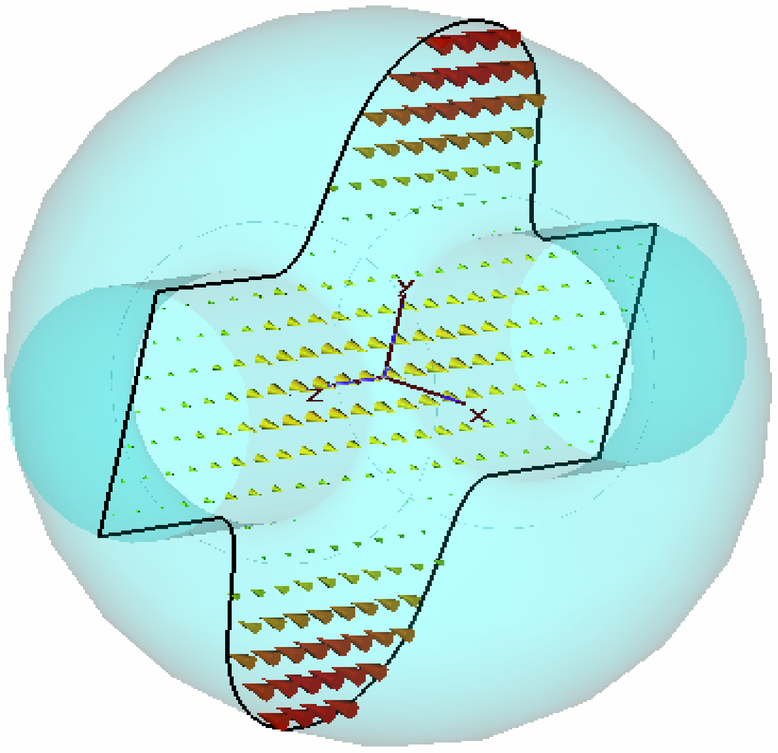
- The aim of our work is development of device and method to find the position of electric axes of accelerating mode TM 010 – 9 and dangerous dipole modes, investigate the difference between them and the geometrical axis and also analyze the transversal kick to the beam. The required precision is 0.1 to 0.2 mm.

- For the beginning, experiments with TM 110 dipole mode has been performed, because it is the easiest mode to investigate.

TM 110 in the single cell cavity



Electric field



Magnetic field

Method of measurement

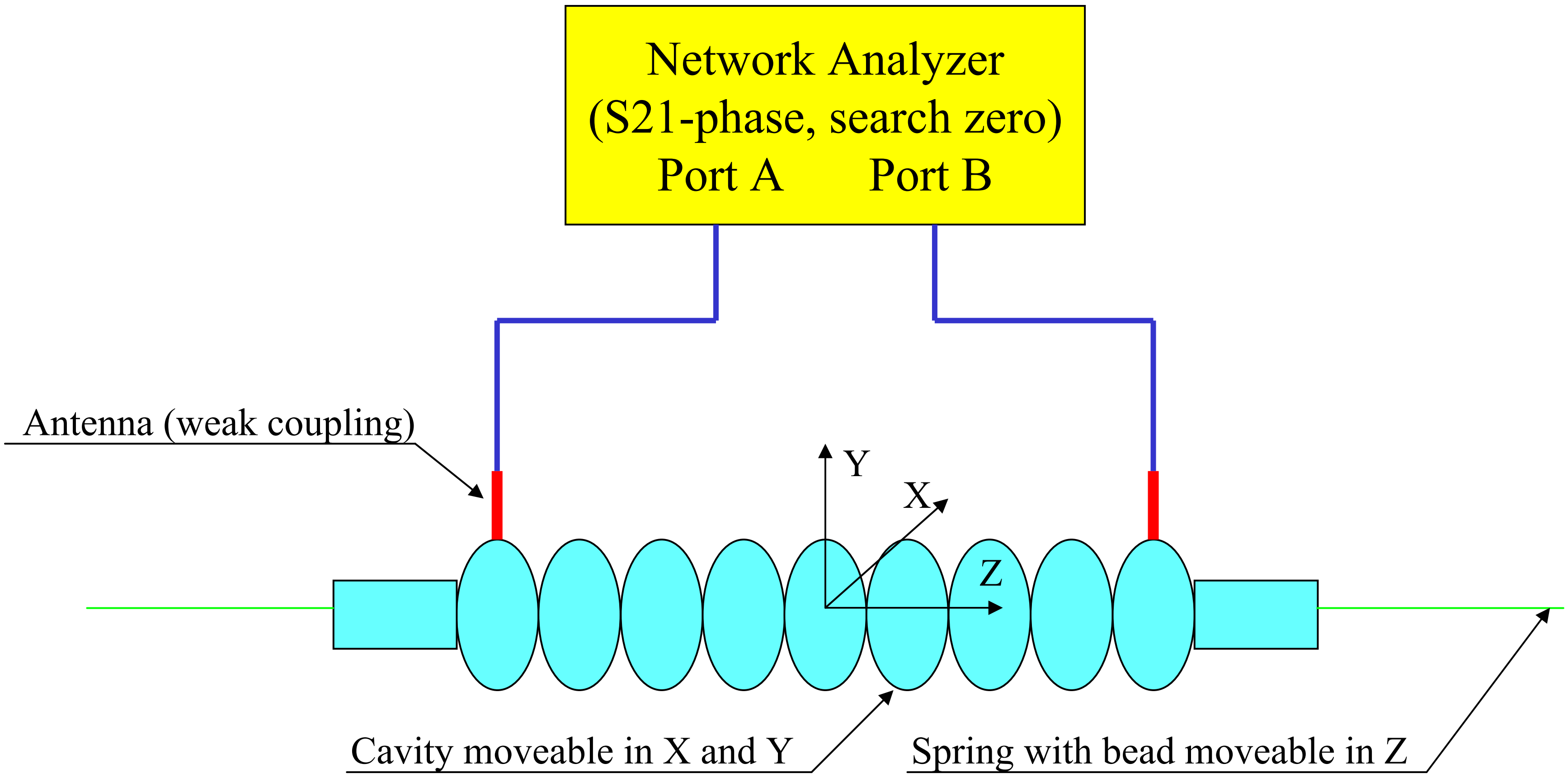
- The field was observed by the bead – pull method, a perturbation object was a copper needle, 10 mm long, 0.4 mm in diameter made of a very thin copper wire wounded around the pulling polyamide spring.

- The bead was positioned to the center of measured cell

- The cavity was movable in both directions transversal to the cavity axis

- The field was excited and measured by antennas placed in holes in outer cavities, the position has been found to excite only one polarization

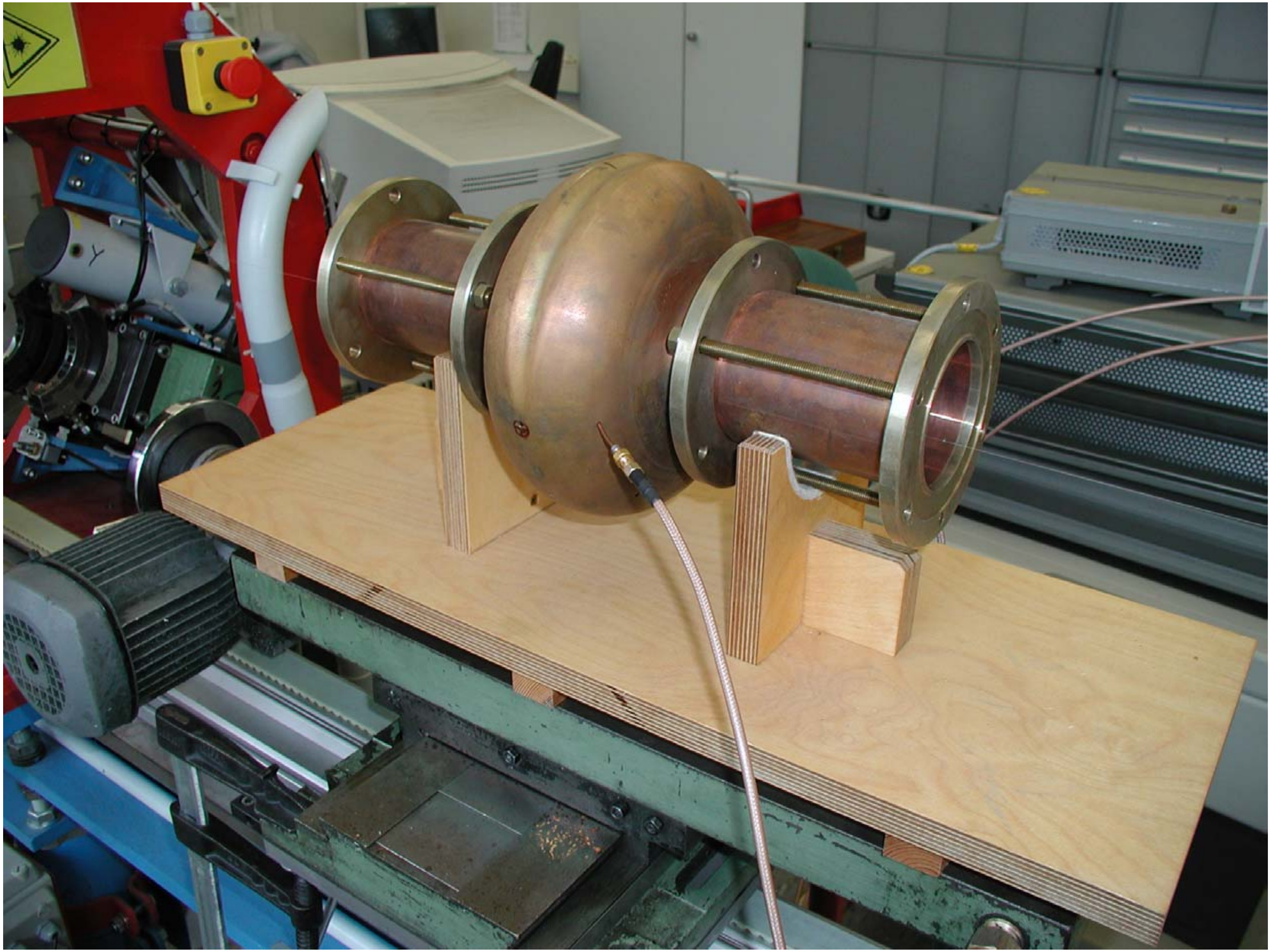
Method of measurement



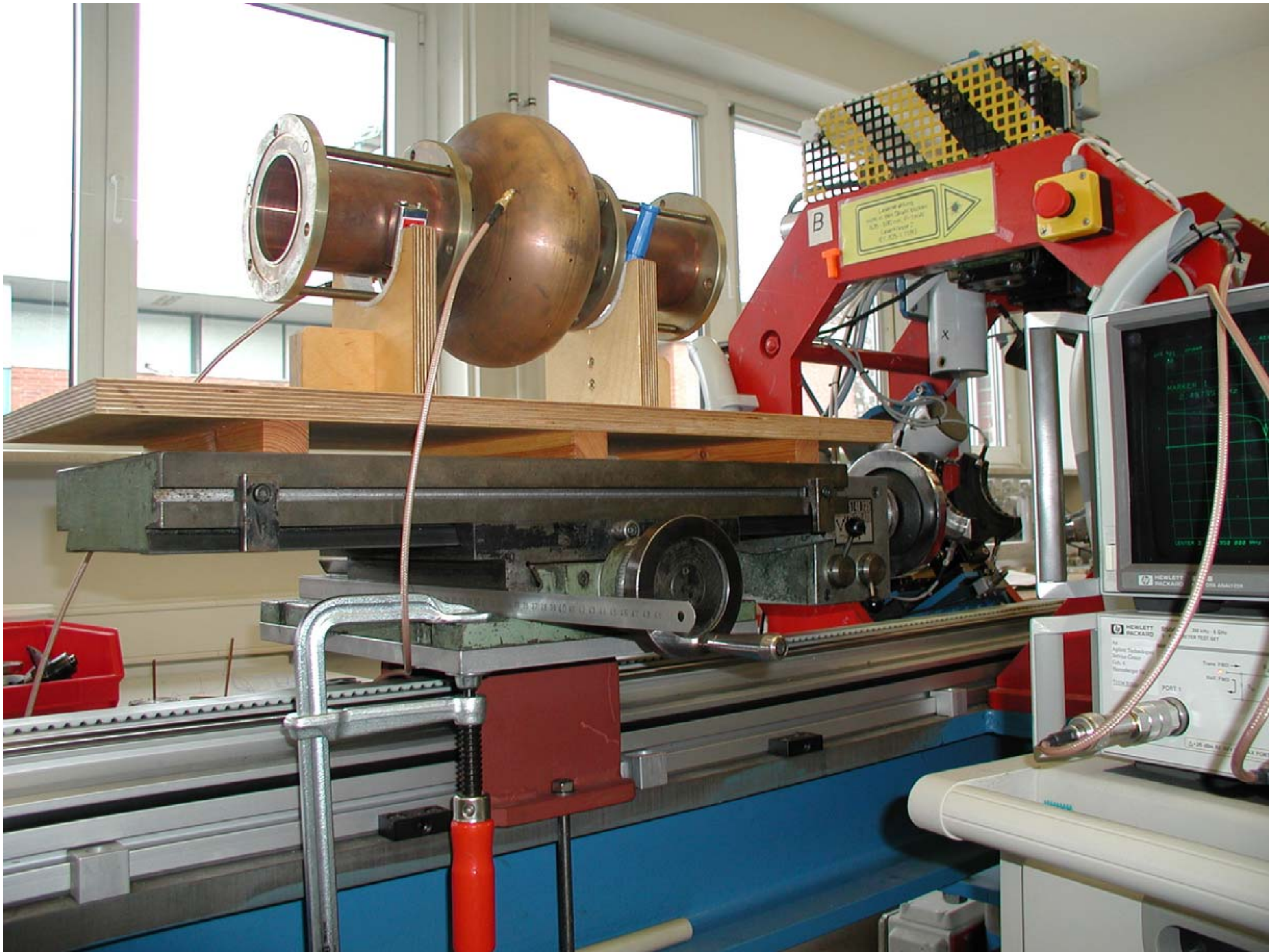
Experiments with single cell copper cavity

- We have used an asymmetrical cavity, so the electrical axes were significantly displaced
- As a moving mechanism for the cavity a table from old miller has been used
- The movement precision was 0.05 mm, but unfortunately the start point was not located precisely (only by eye).
- The axis of TM 110 mode have been measured with a copper needle
- The step of data acquisition was 1 mm

Experiments with single cell copper cavity

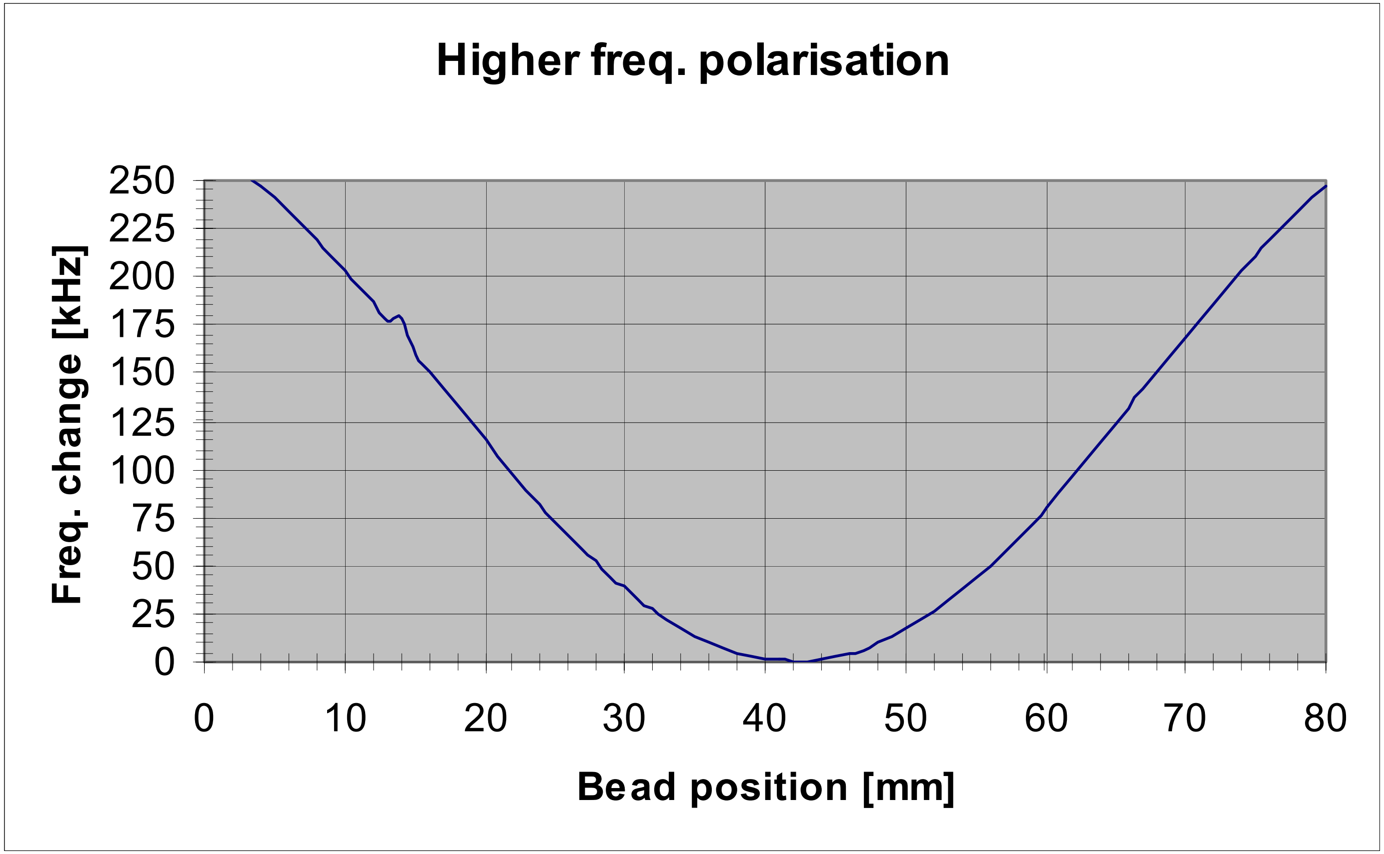


Experiments with single cell copper cavity



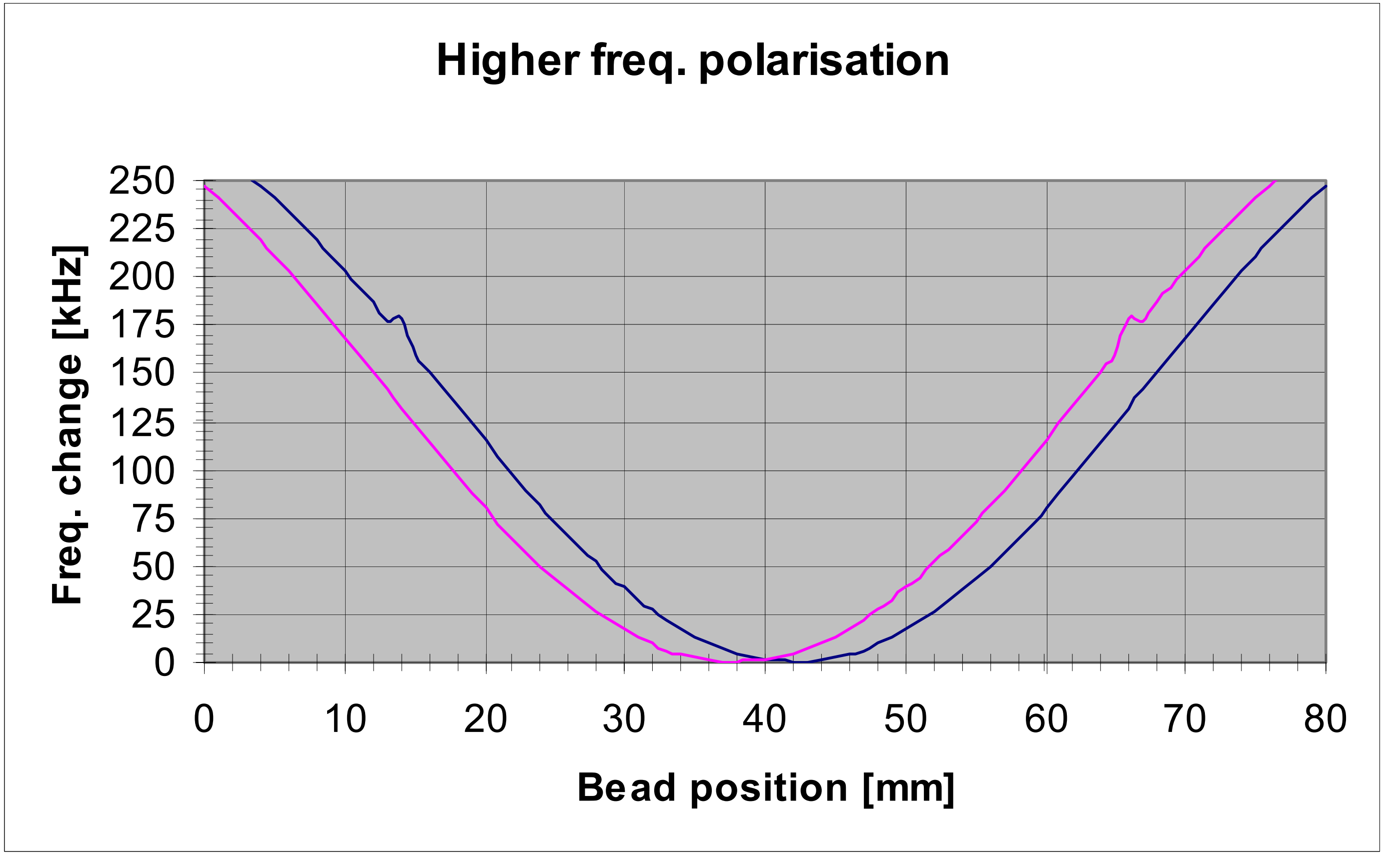
Experiments with single cell copper cavity

- Here is the transversal electric field distribution for the polarization with higher resonant frequency



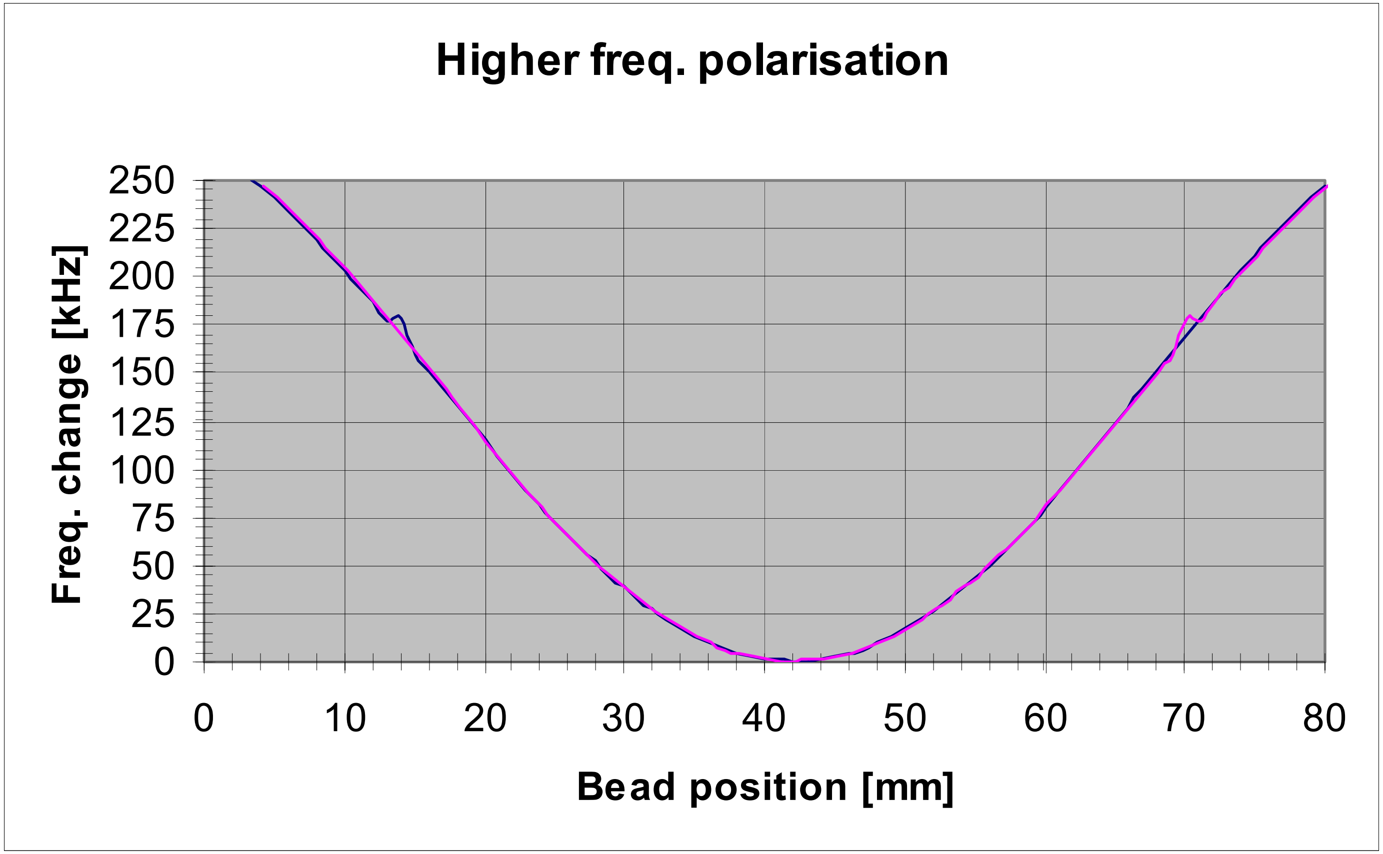
Experiments with single cell copper cavity

- The second curve is the mirror of the first one



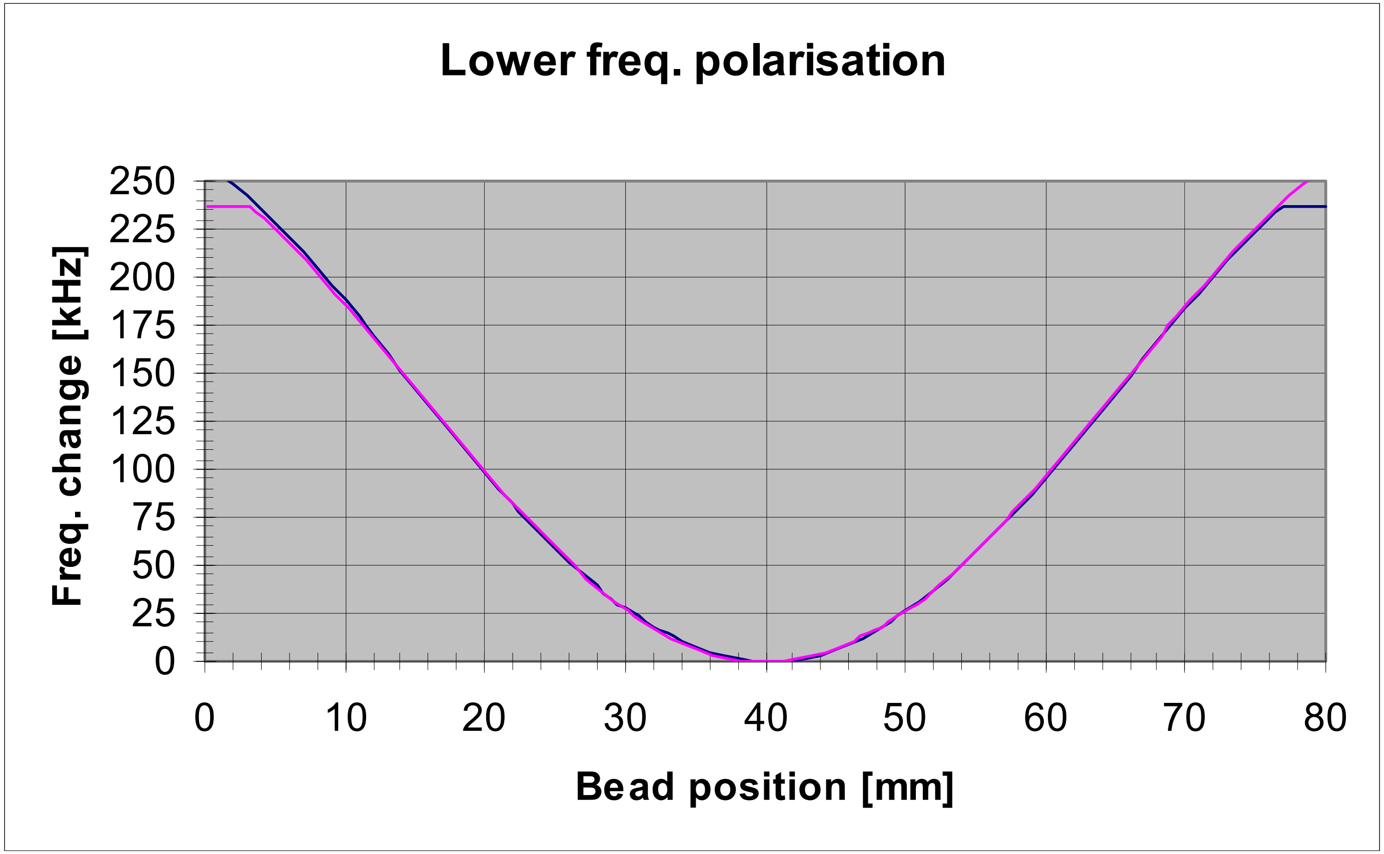
Experiments with single cell copper cavity

- The offset between the original and mirror is two times the axis displacement (displacement = 2.1 mm)



Experiments with single cell copper cavity

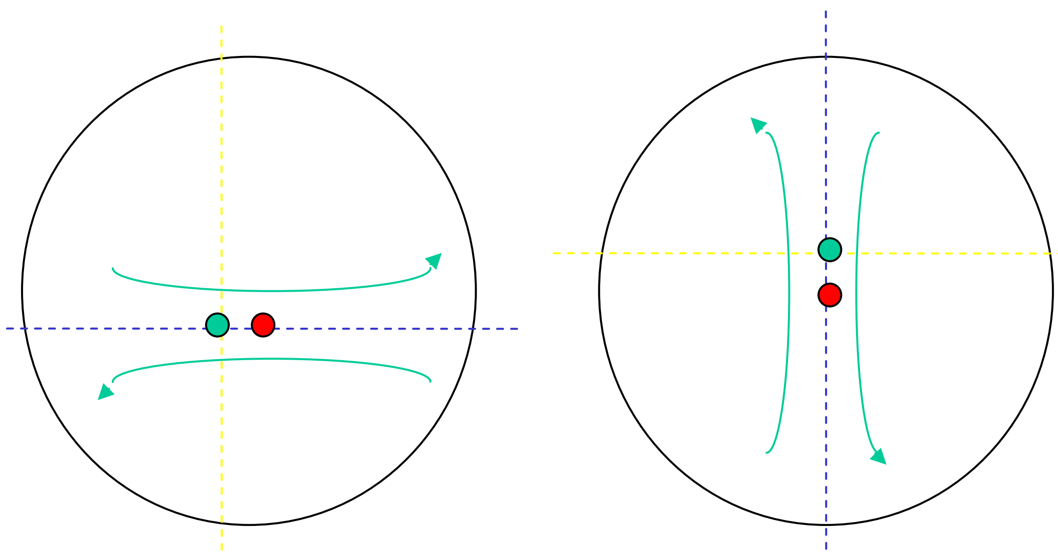
- And the same for the polarization with lower resonant frequency (displacement = 0.15 mm)



Experiments with single cell copper cavity

Results:

- We have found a point laying on the line of minimal electric field, one for each polarization. The intersection of electrical axis and the measurement plane lays in the same line. To find the second coordinate we have to investigate the field also in the perpendicular direction.



Direction of bead moving

E-field and its found minimum

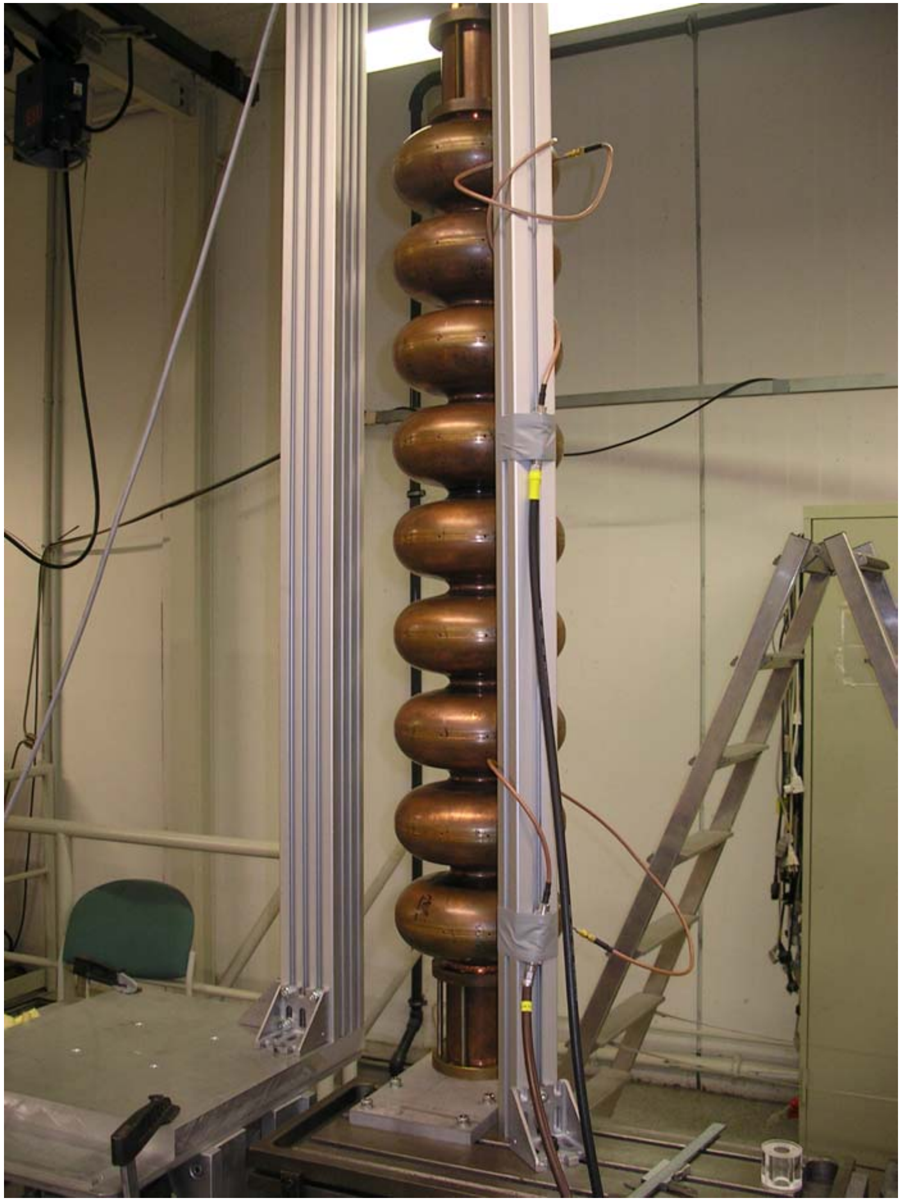
Electrical axis intersection point for given polarization

- The displacement has been found by graphical method, the accuracy is 0.1 mm

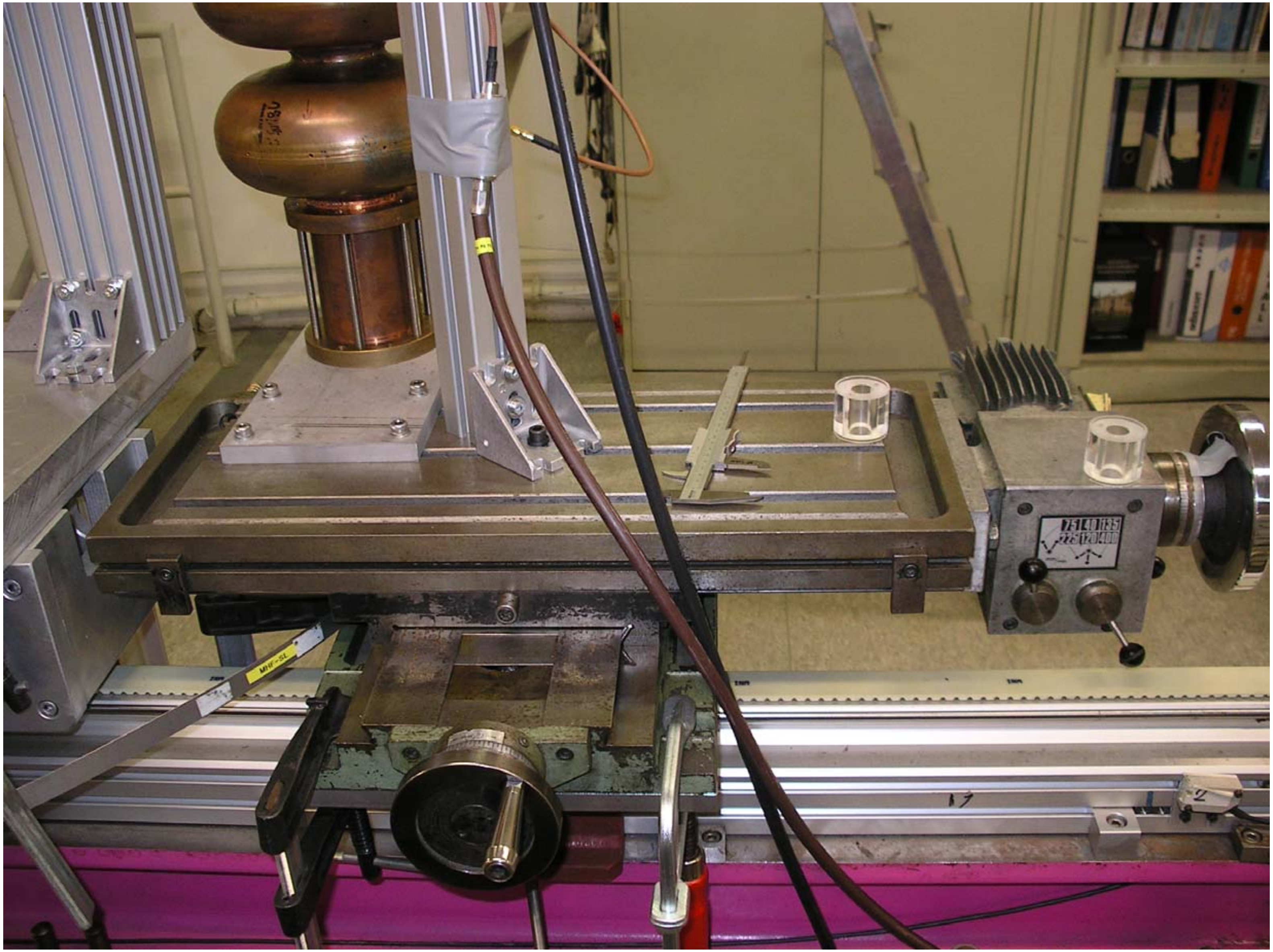
Experiments with 9-cell copper cavity

- After successful experiment with the single cell cavity we have decided to build a simple setup for experiments with 9-cell cavity
- The used cavity has eccentricity about 2 mm and that was good for this purpose
- The same positioning mechanism was used, so the precision of transversal movement was 0.05 mm, but precise fixing of starting point on the iris was impossible. With using of metal needle as a bead the both polarizations of modes TM 110-4 and TM 110-5 (maximum shunt impedance from all TM 110 modes) have been measured

Experiments with 9-cell copper cavity



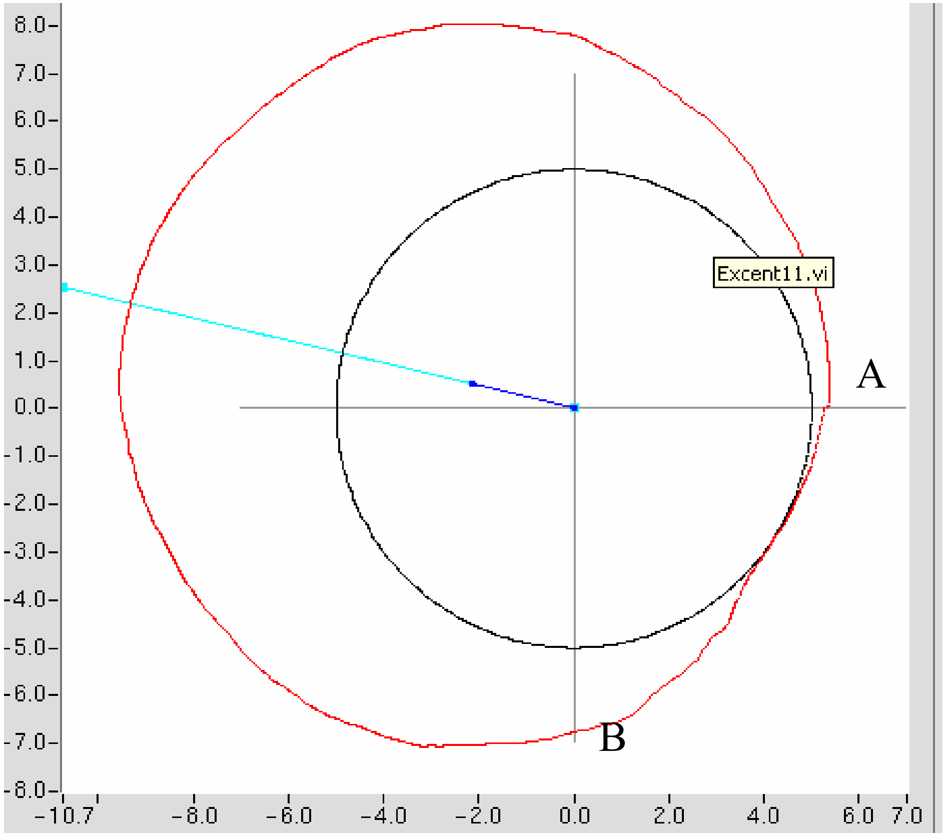
Experiments with 9-cell copper cavity



Experiments with 9-cell copper cavity

Experiments with 9-cell copper cavity

- Polarizations TM110-4-L and TM110-5-H were located in the plane A
- Polarizations TM110-4-H and TM110-5-L were located in the plane B (perpendicular to the A)
- The field in some cells was wery weak and measurement was not possible
- Mechanical measurement shows the maximal eccentricity close the plane A (cell 5 is on the picture)

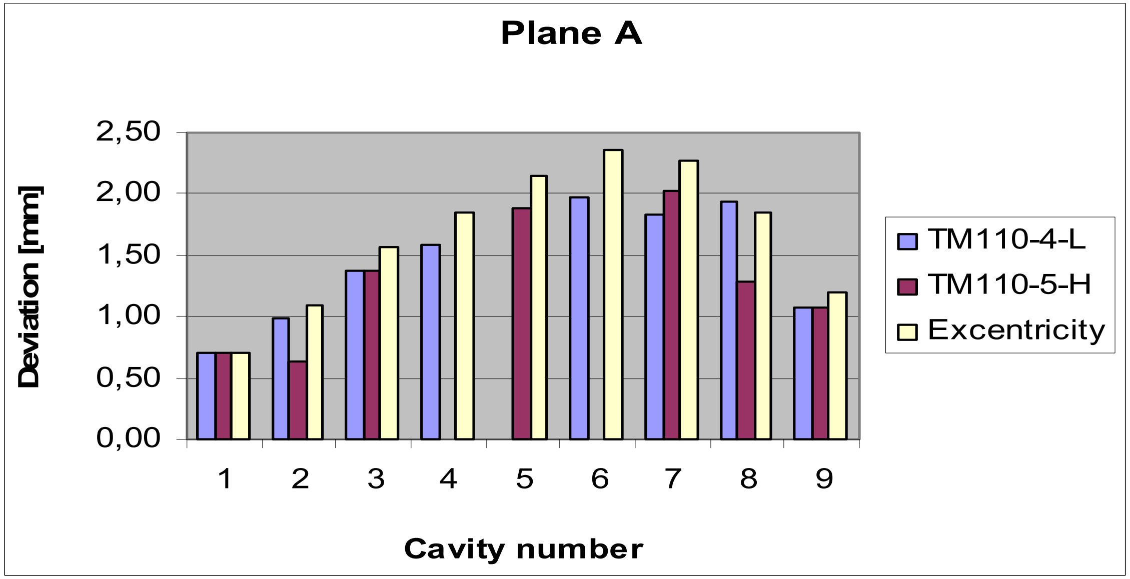


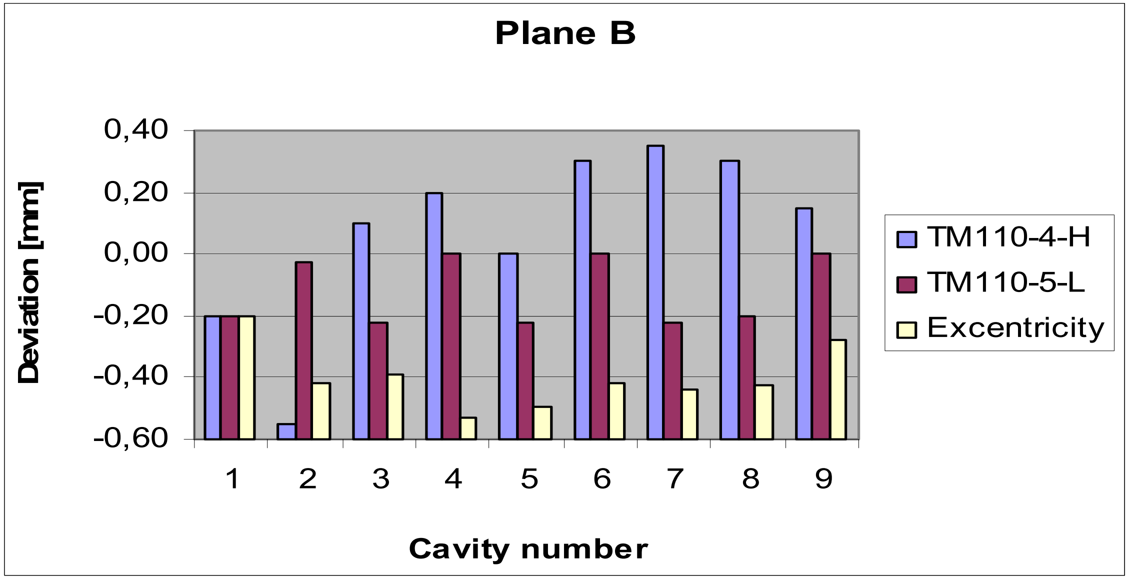
Cell. nr.	A-tube	1	2	3	4	5	6	7	8	9	B-tube
Eccentr.	0.00	0.74	1.17	1.61	1.92	2.21	2.39	2.31	1.89	1.23	0.00
Angle	13.64	164.26	158.62	165.70	164.20	166.74	170.10	168.99	167.08	167.21	13.64

Experiments with 9-cell copper cavity

- As was mentioned before, there was a problem with fixation of starting point of the bead on the iris, so the absolute values are loaded by additive error. To compare the cell to cell displacement, the values on graphs are corrected (first cell is equaled to the mechanical eccentricity)

- Missing bars mean insufficient field in cells to make a measurement





Conclusions

- The location of electrical axis can be found with requested precision of 0.1 mm as a consequence of very good field symmetry (tested with single cell cavity)
- About 9-cell cavity – at this moment it is not possible to say, whether variations in order of 0.1 mm between different modes and mechanical measurement are real (temperature drift of resonant frequency, insufficient mechanical precision, discrete number of holes for antennas)
- For necessary higher accuracy a precise mechanical setup and constant cavity temperature is required
- The measurements of axes of other modes has to be done
- Each mode has its own electrical axis, so the appropriate data processing has to be found to know, what we will call as a unique electrical axis of the cavity