BULGARIAN ACADEMY OF SCIENCES
INSTITUTE OF ELECTRONICS
"Acad. Emil Djakov"

MODELING, SIMULATION AND COMPUTER AIDED DESIGN (CAD) OF POWERFUL GYROTRONS FOR FUSION RESEARCH

(Association EURATOM-INRNE Task 2.1.2 "Development of computer codes to describe the behavior of high-power gyrotrons")

Prof.Dr.Dr.h.c. M.Thumm, Dr. S. Kern, Dr. S.Illy

Prof.Dr. M.Q.Tran, Dr. J.-P.Hogge, Dr. S.Alberti, Dr. T. M. Tran

Dr. S. Sabchevski – principal investigator
Dr. R. Enikov, Dr. E. Balabanova, M. Damyanova, E. Vasileva

Prof. Dr. I. Zhelyazkov, Dr. P. Dankov, Dr. P. Malinov

MOTIVATION, GOALS AND EXPECTATIONS

MOTIVATION

Modeling, simulation and computer aided design (CAD) based on numerical experiments are essential tools for development, optimisation and study of high-power gyrotrons used for electron cyclotron resonance heating (ECRH) and electron cyclotron current drive (ECCD) of magnetically confined fusion plasma in various thermo-nuclear reactors. The research on this topic is being pursued by a Bulgarian team from the Institute of Electronics of the Bulgarian Academy of Sciences (IE-BAS) and from the Faculty of Physics of Sofia University (FP-SU) in a collaboration with the Institute for Pulsed Power and Microwave Technology at FZK (IHM-KIT), Karls-ruhe, Germany and Centre de Recherches en Physique des Plasmas École Polytech-nique Fédérale de Lausanne (CRPP-EPFL), Switzerland.

GOALS AND OBJECTIVES

DEVELOPMENT OF ADEQUATE, SELF-CONSISTENT AND INFORMATIVE PHYSICAL MODELS (FORMU-LATED IN 2D and 3D) AND THEIR IMPLEMENTATION IN EFFICIENT, PORTABLE, AND EXTENSIBLE PROBLEM-ORIENTED NUMERICAL PACKAGES FOR SIMULATION AND COMPUTER AIDED DESIGN (CAD) OF THE NEXT GENERATION OF POWERFUL GYROTRONS FOR ELECTRON CYCLOTRON RESONANCE HEATING (ECRH) AND ELECTRON CYCLOTRON CURRENT DRIVE (ECCD) OF MAGNETICALLY CONFINED FUSION PLASMAS BASED ON EFFICIENT NUMERICAL METHODS AND ALGORITHMS; ADVANCED PROGRAMMING TECHNOLOGIES FOR STATE-OF-THE-ART COMPUTER SYSTEMS.

EXPECTATIONS

USE THE DEVELOPED TOOLS FOR

- **ANALYSIS, OPTIMIZATION AND DESIGN OF HIGH PERFORMANCE ELECTRON-OPTICAL SYSTEMS (EOS) AND RESONANT CAVITIES FOR HIGH-POWER GYROTRONS**

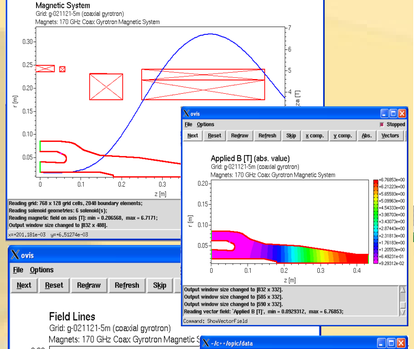
GET

- **DEEPER PHYSICAL INSIGHT IN THE OPERATION OF HIGH-POWER GYROTRONS AND IN THE FACTORS AFFECTING THEIR PERFORMANCE (EFFICIENCY, STABILITY, MODE PURITY)**

CONTRIBUTE TO

- **A BREAKTHROUGH IN ACHIEVING RECORD LEVELS OF EFFICIENCY AND OUTPUT POWER (MEGAWATT CLASS) OF GYROTRONS FOR FUSION PLASMA HEATING**

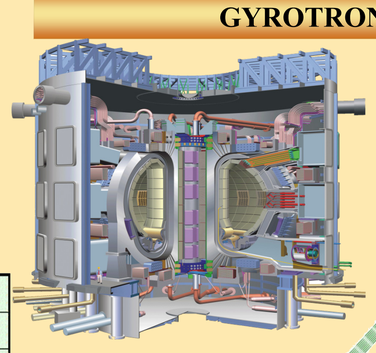
2 MW, 170 GHz Coaxial-Cavity Gyrotron for ITER



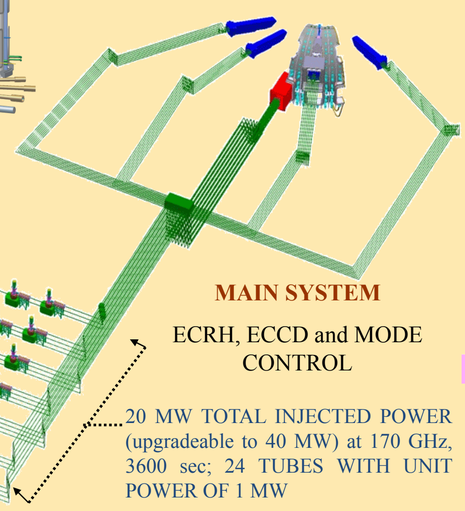
Design Specifications

Design mode	$TE_{34,19}$
Output frequency	170 GHz
mm-wave output power	2 MW
Beam current	< 75 A
Accelerating voltage	< 90 kV
Cavity magnetic field	6.87 T
Output efficiency (w/o SDC)	33 %
Output efficiency (SDC)	> 50 %

GYROTRONS FOR FUSION



- HEATING
- CURRENT DRIVE
- MODE CONTROL
- PLASMA START UP



START UP SYSTEM

2.5 MW at 120 GHz, 3 s

3 TUBES OF 1 MW

MAIN SYSTEM

ECRH, ECCD and MODE CONTROL

20 MW TOTAL INJECTED POWER (upgradeable to 40 MW) at 170 GHz, 3600 sec; 24 TUBES WITH UNIT POWER OF 1 MW

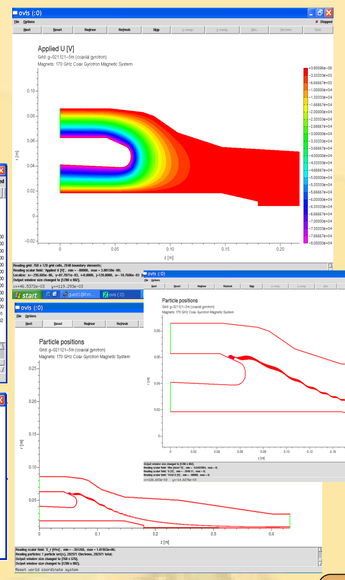
ITER: TOSHIBA/JAEA (JA) | ITER: GYCOM/IAP (RF) | W7-X: CPI (USA) | W7-X: TED/FZK/CRPP (EU)

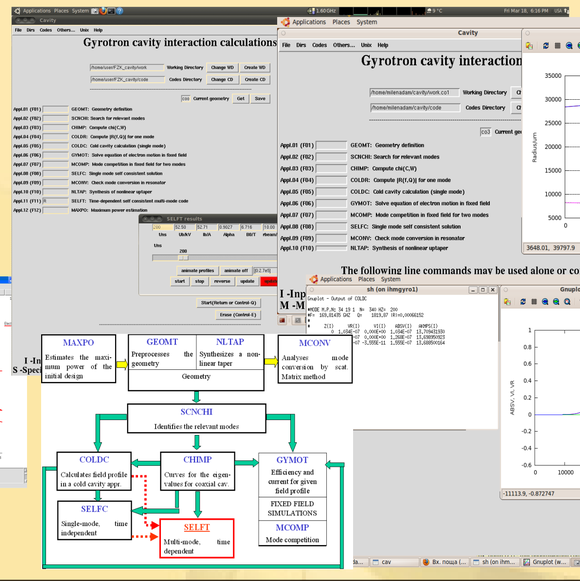
Megawatt-class cylindrical cavity gyrotrons for ITER (170 GHz) and W7-X (140 GHz)

ILLUSTRATIVE RESULTS OF NUMERICAL EXPERIMENTS

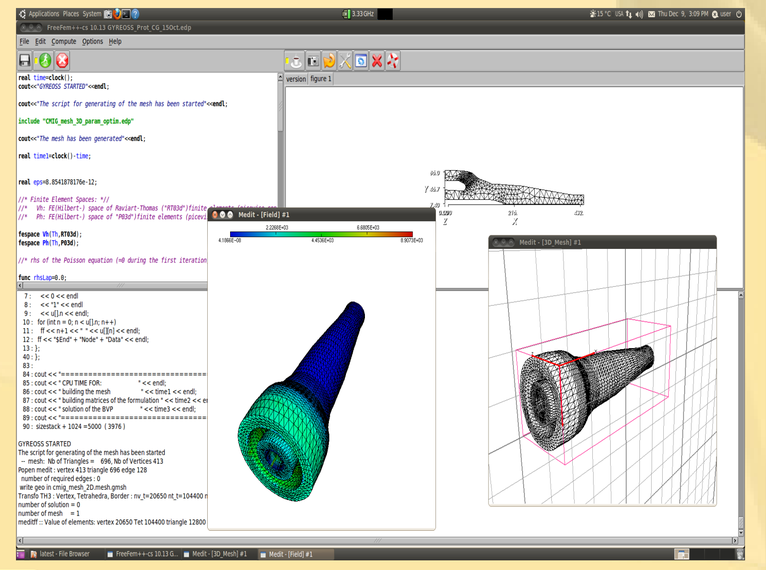
RAY TRACING OF THE EOS USING ESRAY PACKAGE

SIMULATION OF THE RESONATOR USING KIT_CAVITY





3D SIMULATION OF A COAXIAL MIG USING GYREOSS



CONCLUSIONS AND FUTURE PLANS

- **A new generation of simulation tools for analysis and computer-aided design of powerful gyrotrons are under development now. They will be used for optimization of the current tubes as well as for designing novel high-performance devices of megawatt class with improved parameters.**

- **The main direction of the future work is focused on the reformulation of the physical models from 2D to 3D andparallelisation of the numerical codes in order to run them on state-of-the art computational platforms (clusters, Grid etc.)**