This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 730871.

WP16: Intense, RF Modulated E-Beams

for Application in Pulsed Electron Lenses

2nd Annual Meeting / Budapest / 10.04.2019

David Ondreka / GSI

Outline

- WP16 Overview
- Task Reports
  - 16.2: System Integration
  - 16.3: Gun and Modulator
  - 16.4: Test Stand
- Summary

WP16: Objectives

- JRA activity among four beneficiaries (CERN, GSI, IAP, RTU)

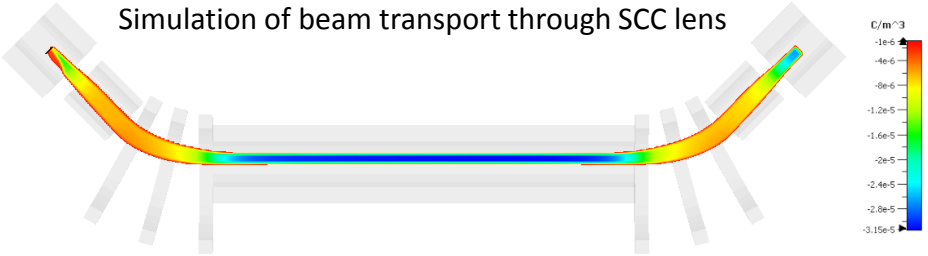
- Manufacturing of an RF modulated electron gun for application in electron lenses
  - High electron currents up to 10 A
  - RF modulated at 0.4 to 1 MHz with a bandwidth of up to 10 MHz
  - Elliptical beam cross section with adjustable aspect ratio
  - Different cathode shapes for matching beam dynamics requirements

- Operation of a test stand for the RF modulated electron gun
  - Normal conducting solenoids for beam transport
  - Instrumentation for probing transverse and longitudinal electron beam profiles

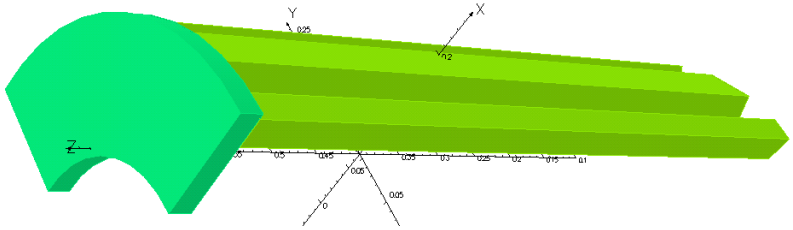
System Integration (16.2): Status

- Goals
  - Layout of a full electron lens for space charge compensation (SCC) in SIS18
  - ✓ Definition of requirements and constraints for SCC gun to be built within ARIES
  - Design of the magnetic system, vacuum system, HV system, diagnostics, support structure, infrastructure
  - ✓ Consideration of ion beam dynamics in presence of SCC electron beam
- Work done in Y2 (GSI)
  - Magnetic layout of lens consistent with electron beam parameters of the SCC gun
    - Electron beam transport simulations performed
    - Magnet aperture and field requirements derived
  - Magnetic design of interaction solenoid
    - Fast ramping for matching adiabatic damping
    - Laminated return yoke to reduce eddy currents
  - Purchasing of gun and collector solenoid started
    - Magnetic design finalized
    - Contract awarded, manufacturing ongoing

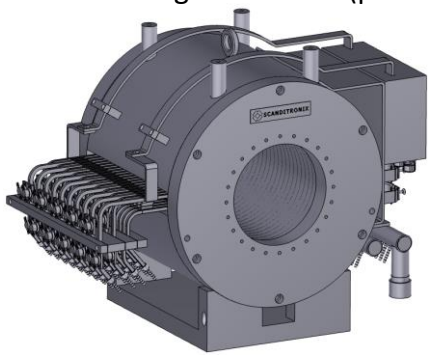
Simulation of beam transport through SCC lens



Design study of interaction solenoid (yoke and end plate)

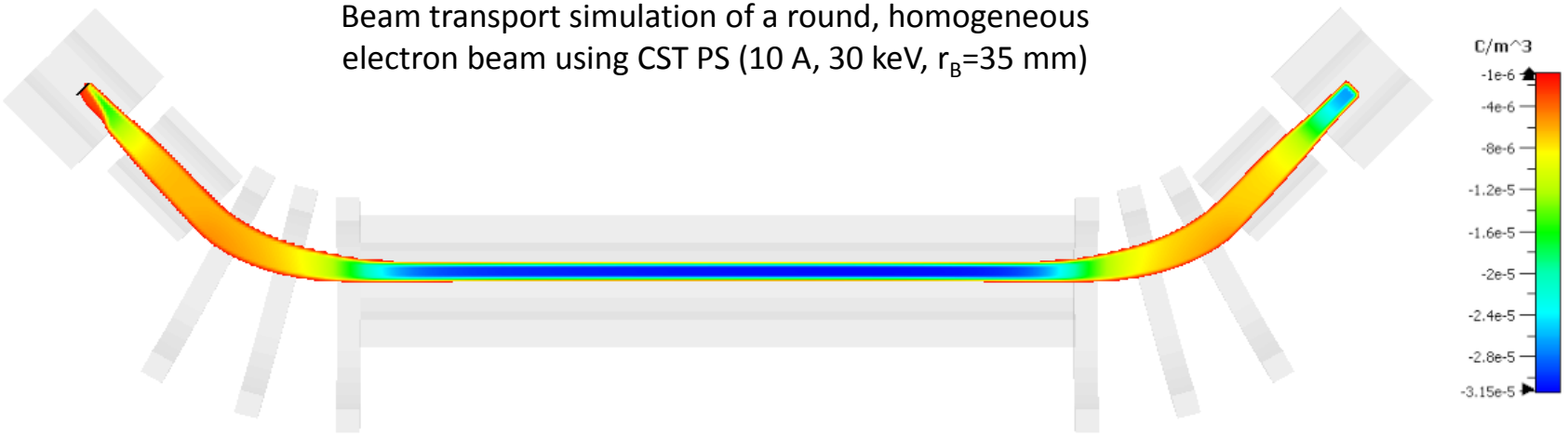


3-D model of gun solenoid (preliminary)

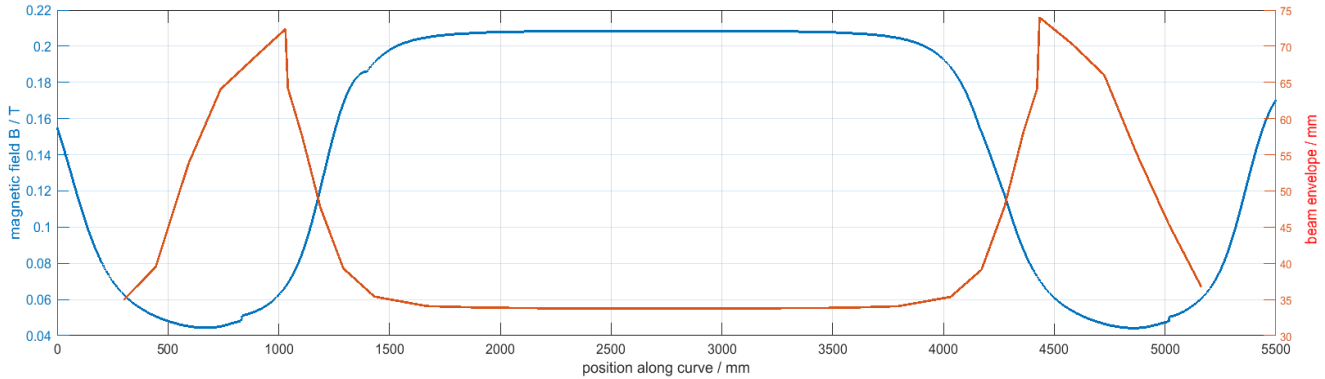


16.2: Magnetic Layout of SCC Lens

Beam transport simulation of a round, homogeneous electron beam using CST PS (10 A, 30 keV, r_B=35 mm)



On-axis magnetic field and beam envelope



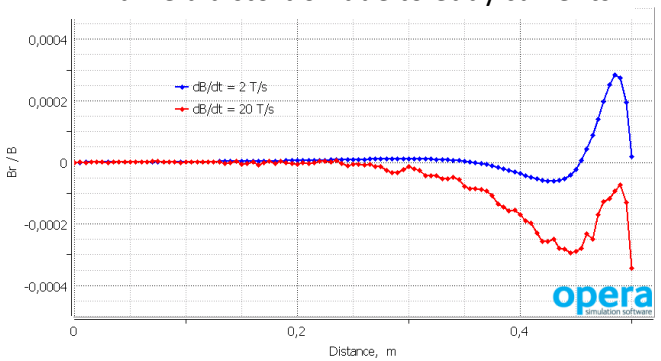
Work performed by K. Schulte-Urlichs

- Magnetic parameters of gun, collector, and interaction solenoid fixed
- Consistent with both round and elliptical beam cross sections
- Magnetic layout of bending sections still preliminary

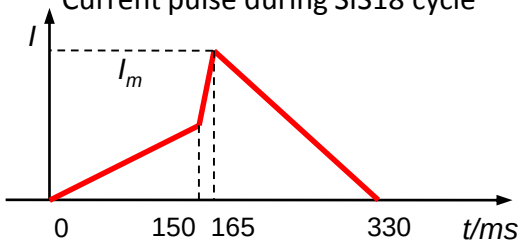
16.2: Design of Interaction Solenoid

- Requirements
  - Good field quality to preserve transverse profile
  - Fast ramping to match adiabatic damping
- Main Parameters
  - Magnetic field on axis: 0.6 T
  - Aperture: 150 mm
  - Total length: 3.4 m
  - **Ramp rate: 20 T/s**
  - Good-field region: r = 40 mm, L = 3 m
  - Field quality: $B_r/B < 5 \cdot 10^{-4}$
- Challenges
  - Current dominated magnet relying on precise positioning of non-uniformly distributed coils
  - Careful design of end plates and return yoke to avoid losses and field distortions through eddy currents

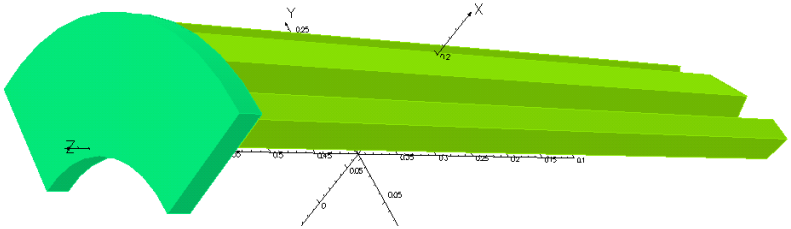
End-field distortion due to eddy currents

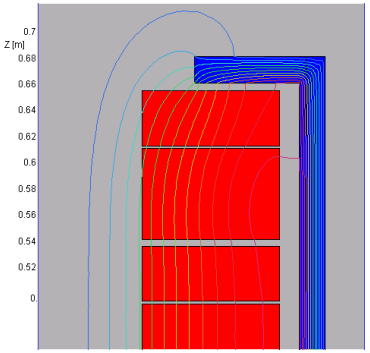


Current pulse during SIS18 cycle



Laminated end plates and return yoke





Coil distribution in end region

Work performed by A. Kalimov

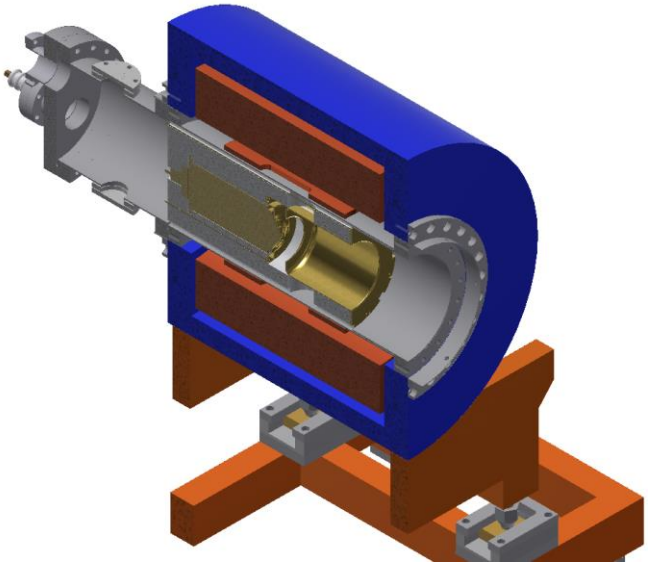
System Integration (16.2): Next Steps

- Reorganization of work in task 16.2
  - Task leader temporarily absent (1.5y maternal leave)
  - Job offer for temporary substitute placed
- Plans for Y3
  - Continuation of work on magnetic system
    - Manufacturing of gun and collector solenoids
    - Preliminary mechanical design of main interaction solenoid based on design study
    - Magnetic design of bending sections (solenoids or toroid)
  - Layout of support structure
- Plans for Y4
  - Refined electron beam transport simulations
    - Consideration of vacuum chamber geometry
    - Error analysis and robustness
  - Layout of XHV system
    - Choice of chamber geometry based on electron beam dynamics simulations

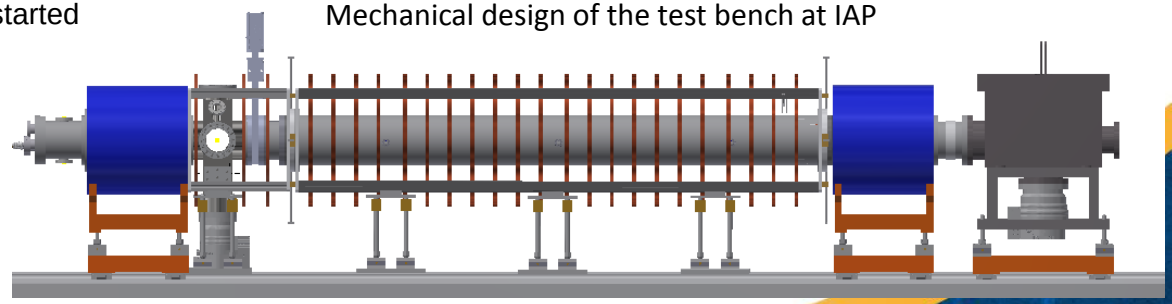
SCC Gun (16.3): Status

- Goals
  - ✓ Design of a gun for the SIS18 SCC lens
    - Grid modulated electron currents up to 10 A
    - Transverse profile matched to elliptical ion beam
    - Full modulation with bandwidth ~ 10 MHz
  - Manufacturing and testing of gun
    - Full gun characterization at CERN test stand
    - Basic powering and performance tests at IAP
- Work done in Y2 (GSI, IAP)
  - Gun design
    - Design of grid-modulated gun for Gaussian transverse profiles finalized
    - Magnetic parameters of gun solenoid and quadrupole for ellipse shaping specified
    - Preliminary engineering design of gun developed
  - Preparation of site for basic tests
    - Layout of test bench completed
    - Installation of test bench components started

Mechanical design of the gun for the SCC lens



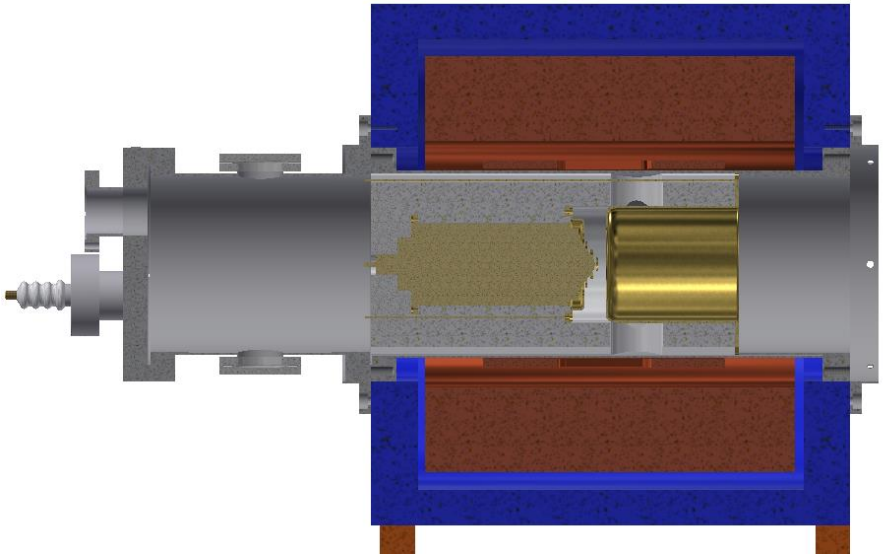
Mechanical design of the test bench at IAP

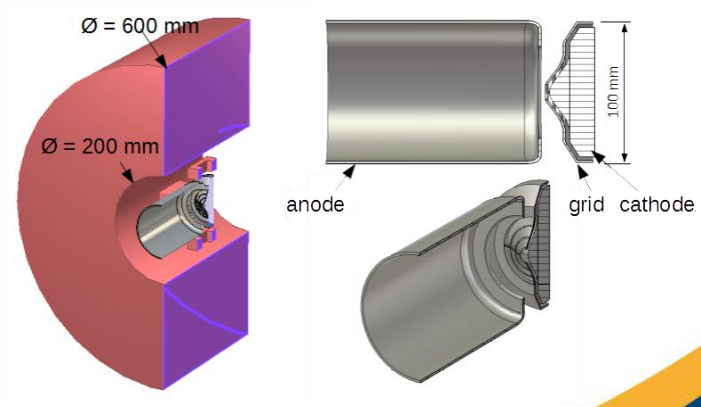


SCC Gun (16.3): Design

- Design considerations
  - Gaussian shaped cathode and grid for creating a Gaussian transverse beam profile
  - Round geometry for easier manufacturing
  - Shaping of elliptical beam cross section using quadrupole field created by air coils
  - Housing on ground potential with insulated cathode
  - Bakeable vacuum structures

SCC Gun Requirements	
Hor./vert. beam size (2σ)	35 mm/20 mm
Cathode radius	26.5 mm
Extraction Voltage	30 kV
Extracted peak current	16 A
Modulated peak current	10 A
Grid voltage	3 kV
Grid capacitance	75 pF
Modulation frequency	0.4 to 1 MHz
Modulation bandwidth	10 MHz
Gun solenoid field	0.6 T
Air coil quadrupole field	0.04 T

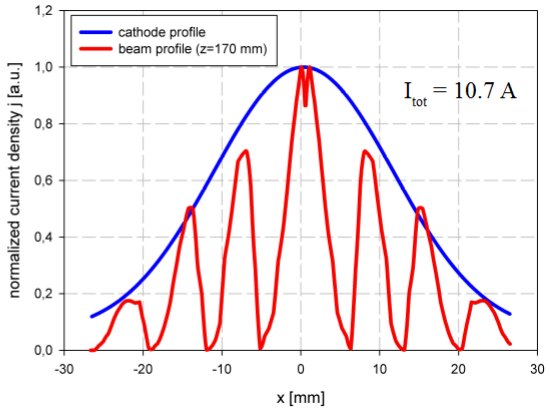




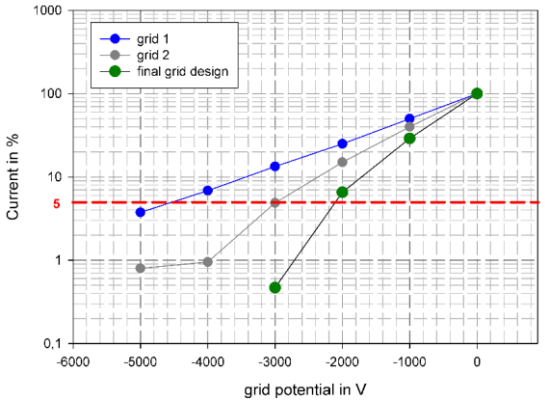
Work performed by K. Schulte-Urlichs

SCC Gun(16.3): Grid Modulation

Final grid design and simulated beam profile

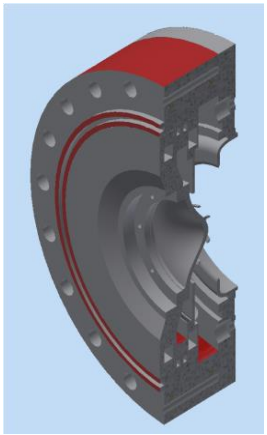


Current vs. voltage for three grid designs



- Reduced power dissipation over anode modulation
- Losses on grid need to be considered
  - Higher extracted currents required (10 A → 16 A)
  - Heat load on grid estimated to be safe for tungsten
- Tests using a Tungsten prototype foreseen at IAP
  - Tungsten cathode and grid received
  - Integration into spare volume ion source planned
  - Ion source‘s filament used for indirect heating
  - Preparations under way

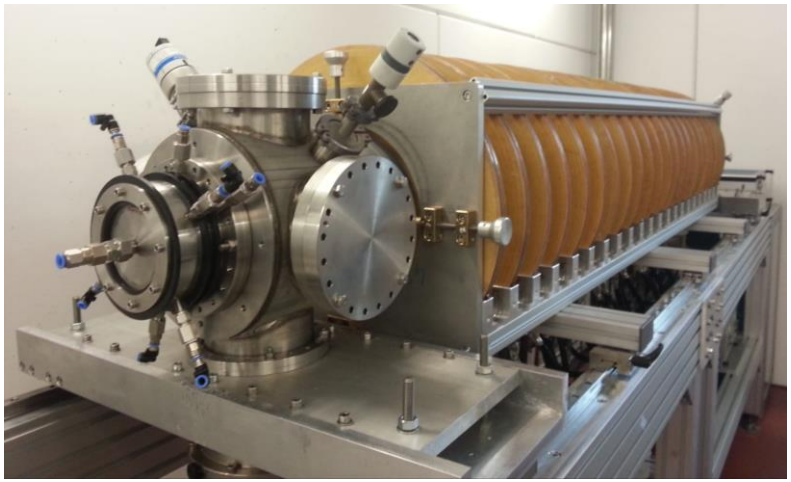
Tungsten prototype for heat load tests

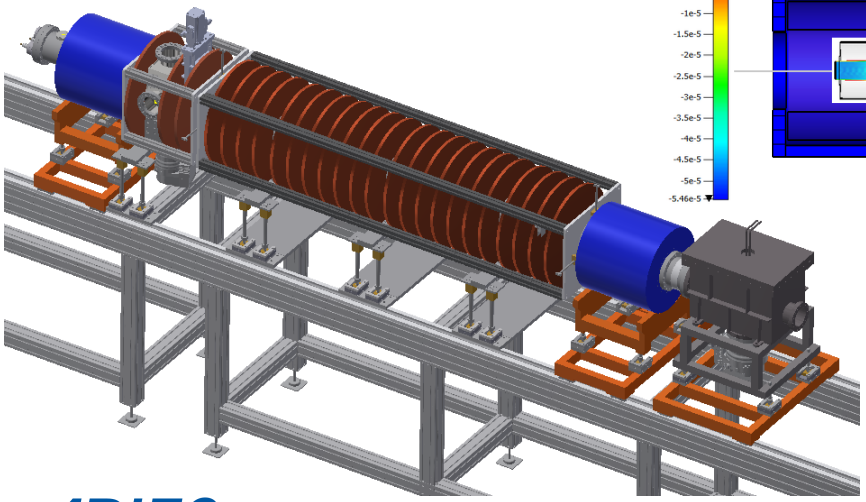


Work performed by K. Schulte-Urlichs

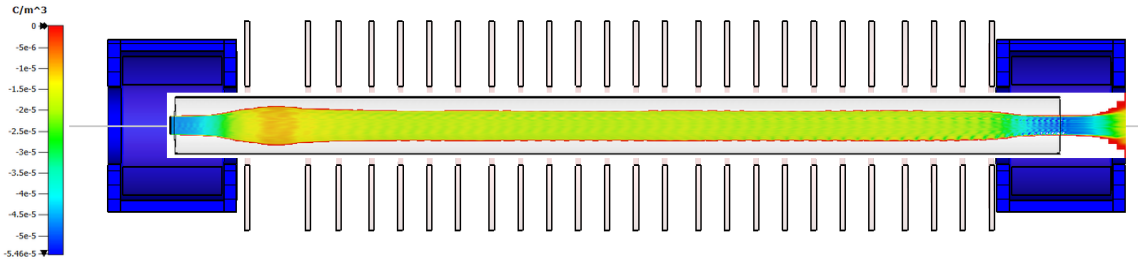
SCC Gun (16.3): IAP Test Bench

- Test bench for the gun at the manufacturing site
  - Basic powering and performance tests
  - Fast turn-around times for optimization of gun design
  - Faraday cup up to 24 kW for long duty cycle tests
- Test bench under preparation
  - Pancake drift solenoid installed
  - Gun and collector solenoids delivered by end of year
- Full characterization of transverse and longitudinal profile at CERN test stand





CST transport simulation for a homogeneous round electron beam (10 A, 30 keV)



Work performed by K. Schulte-Urlichs

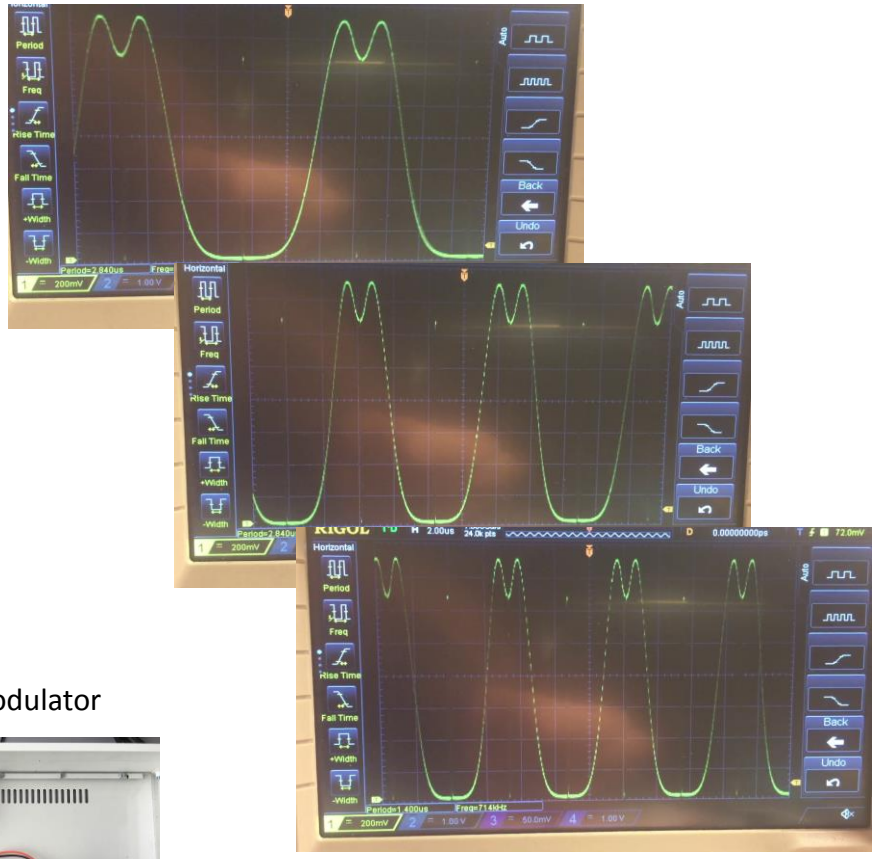
SCC Gun (16.3): Next Steps

- Reorganization of work in task 16.3
  - Task leader temporarily absent (1.5y maternal leave)
  - Task coordination taken over by Martin Droba (IAP)
- Plans for Y3
  - Tests with Tungsten prototype
    - Installation of cathode and grid in ion source
    - Extraction and heat load tests
  - Manufacturing of SCC gun
    - Completion of engineering design
    - Fabrication in IAP workshops
  - Completion of test bench at IAP
    - Installation of gun and collector solenoids
    - Commissioning of diagnostics and data acquisition
  - Commissioning of SCC gun at IAP test bench
    - Basic powering and performance tests
    - Optimization of extraction performance
    - Tests of modulator integration

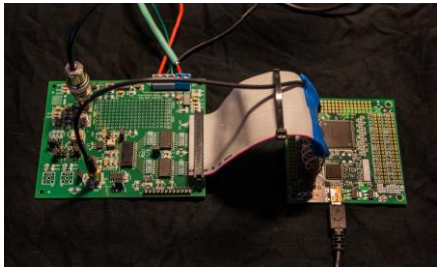
Modulator (16.3): Status

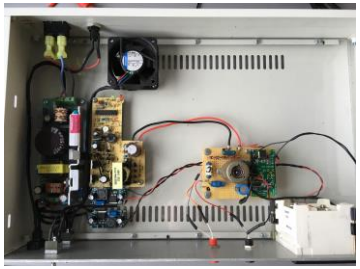
- Goals
  - Modulator for grid modulation of SCC gun
    - Full modulation requiring 3 kV at 0.1 A
    - Bandwidth >= 10 MHz
    - Frequency range 0.4 to 1 MHz
- Work done in Y2
  - Modulator (RTU)
    - Improved prototype built for proof-of-concept
    - Signal generator for sweeping different wave forms over frequency range implemented
    - Tests at IAP next week
  - Proof-of-concept experiment (IAP)
    - Modifications to set-up for proof-of-concept experiment for reduced stray capacitances

Frequency sweep of Gaussian double bump profile



Working prototypes of signal generator and modulator





Work performed by P. Apse-Apsitis, I. Streiks, J. Van De Pol

Modulator (16.3): Next Steps

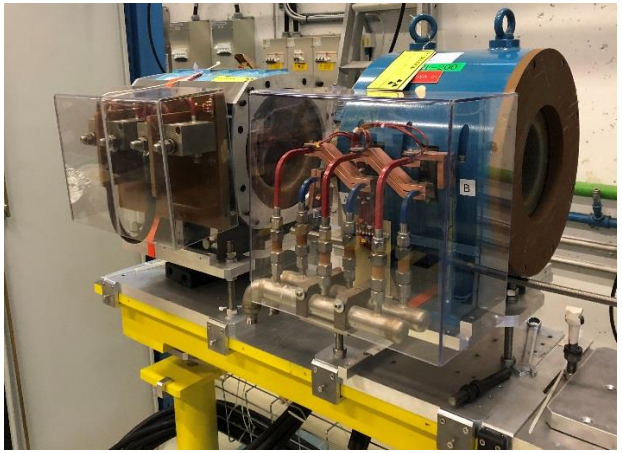
Plans for Y3

- Proof-of-concept experiment at IAP
  - Commissioning of mini-gun with improved modulator
  - Characterization of longitudinal profile of modulated electron beam from mini-gun
  - Testing of various longitudinal profile shapes
- SCC gun modulator
  - Manufacturing of final modulator
  - Integration with SCC gun at IAP
  - Powering tests with SCC gun at IAP

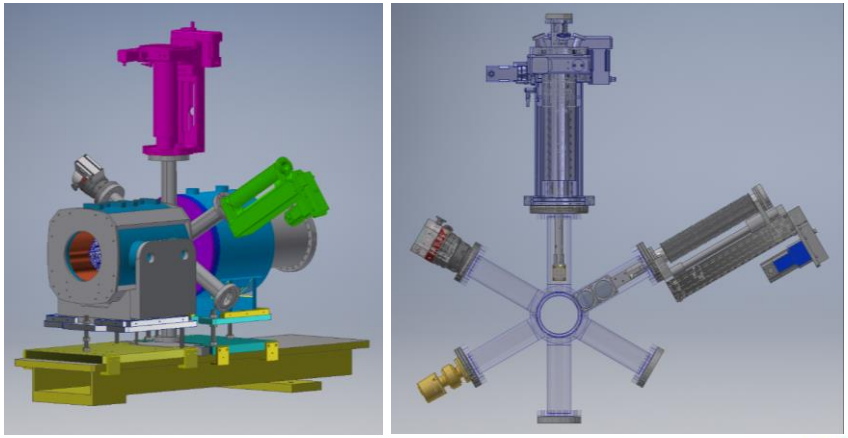
CERN Test Stand (16.4): Status

- Goals
  - Design and construction of test stand for qualifying both CERN HEL gun and GSI SCC gun
  - Characterization of electron beam with respect to longitudinal and transverse beam profiles
- Work done in Y2 (CERN)
  - Design of first stage optimized
  - Facility for test stand prepared
    - Electrical power connection established
    - Cooling water plant installed
  - Test stand under installation
    - Solenoids mounted on test bench
    - Diagnostic box under construction

Solenoids mounted on test stand



Design of test stand and diagnostic box



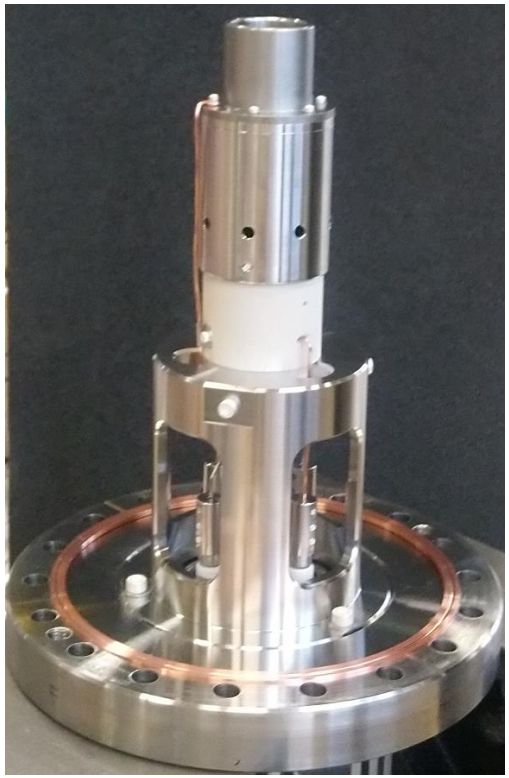
Work performed by S. Sadovich

Test Stand: Next Steps

Plans for Y3

- Commissioning of first stage of test stand
  - Completion of installation
  - Commissioning of power converters
  - Commissioning of diagnostic tools
- Adaptations for SCC gun
- Characterization of HEL gun
  - Gun current emission yield vs. cathode temperature (800 to 1000 °C) and extraction voltage (0 to 10 kV)
  - Transverse profile of electron beam vs. extracted current and magnetic field in the gun solenoid

Gun of CERN Hollow Electron Lens



Design of CERN EN-MME group (D. Perini), scaling from FNAL design (G. Stancari)

Summary

- WP16 objectives and partners introduced
- Status and outlook given for each task
  - 16.2: System integration
    - Magnetic layout advanced to define boundary conditions and requirements for SCC gun
    - Gun and collector solenoids ordered, magnetic design of main solenoid done
  - 16.3: SCC gun and modulator
    - Mechanical design of grid modulated gun with quadrupole for shaping ellipse completed
    - Tungsten prototype of cathode and grid built, soon to be tested with volume ion source
    - Improved modulator and signal generator to be tested next week with mini-gun at IAP
  - Electron gun test stand
    - First stage of test stand under installation and commissioning
    - Final adjustments for integration of SCC gun under way

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 730871.

Thanks to all the collaborators who contributed and continue to contribute to the project:

Adriana Rossi, Sergey Sadovich (CERN)

David Ondreka, Kathrin Schulte-Urlichs (GSI)

Oliver Meusel, Martin Droba (IAP)

Peteris Apse-Apsitis, Ingars Streiks, Johann Van De Pol (RTU)