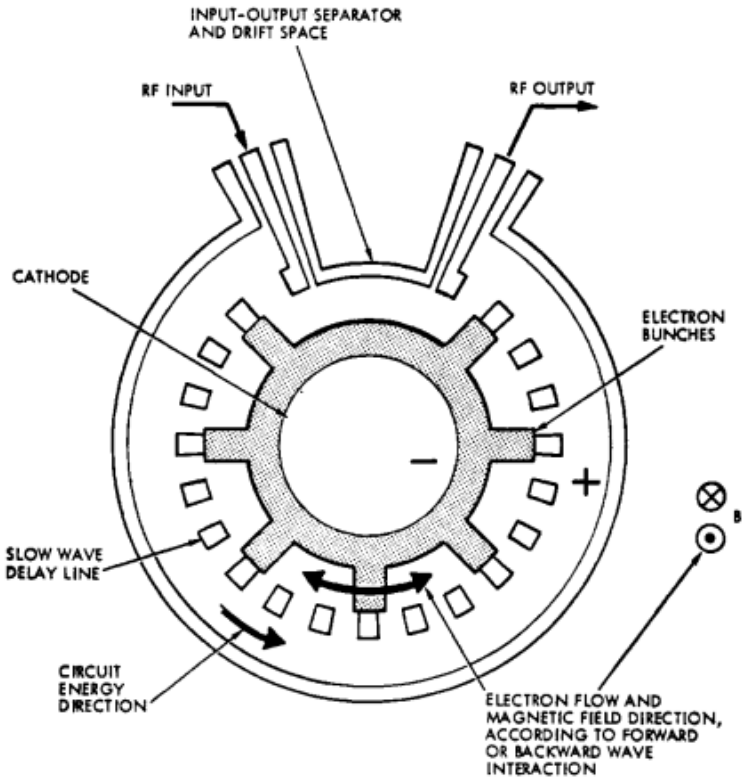
Development of Highly Efficient Megawatt Class Cross Field Vacuum Tube Amplifier for Particle Accelerators Driven by a Solid State Power Amplifier at 750 MHz

Lead Organization and IFAST member: FREIA laboratory at Uppsala University

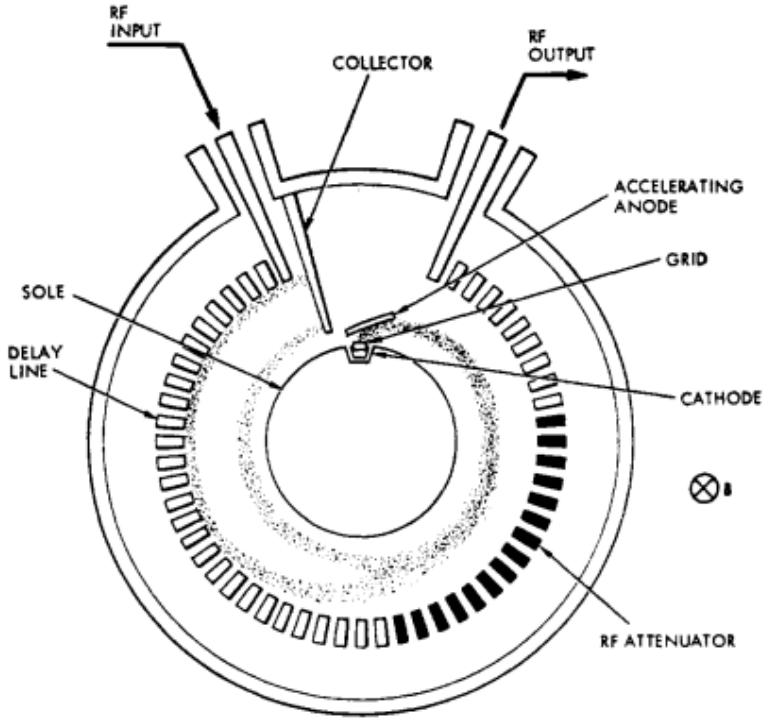
Industrial partners: Scandinova AB and Exir Broadcasting AB

Dragos Dancila and Anshu Sharan Singh
Uppsala University

Technical scope:
Cross-Field Amplifier (CFA)

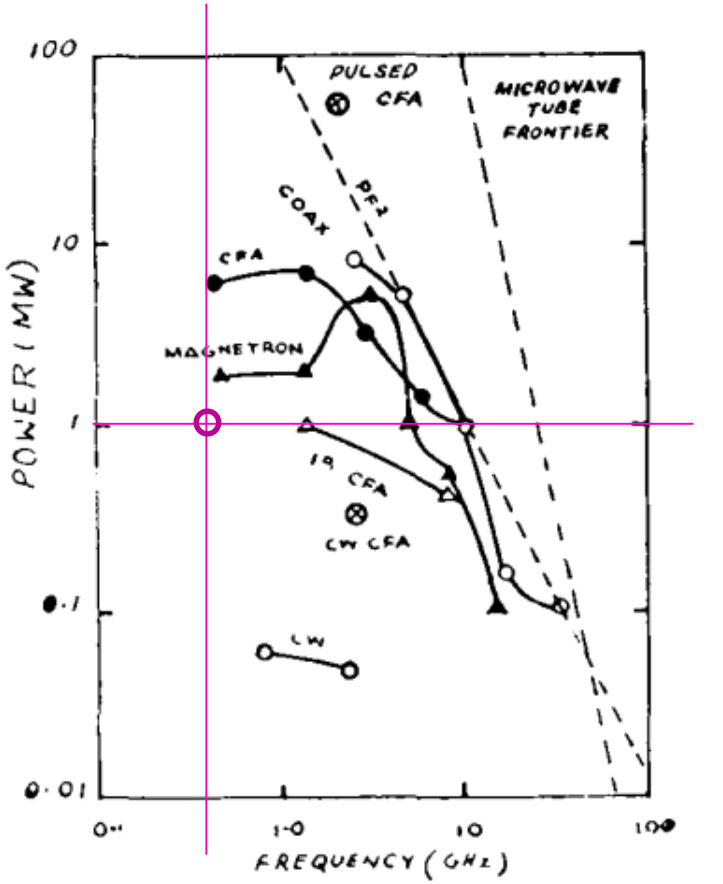


CONTINUOUS CATHODE EMITTING SOLE CFA (CC-CFA)
FORWARD OR BACKWARD WAVE



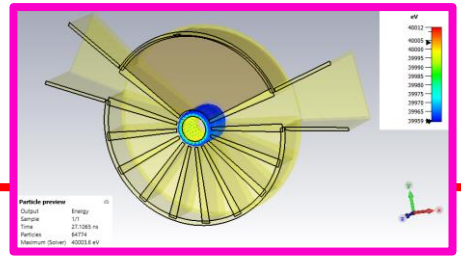
The Continuous-Cathode (Emitting-Sole)
Crossed-Field Amplifier

JOHN F. SKOWRON

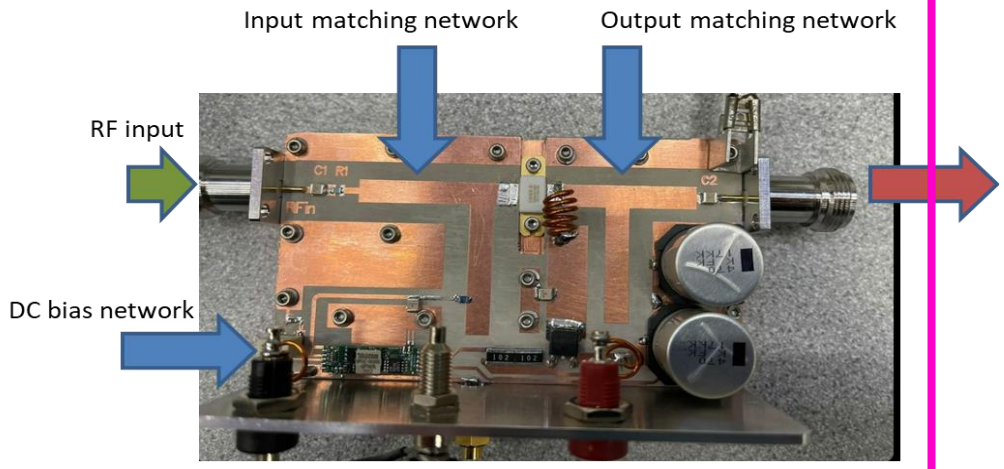


Crossed-Field Devices — State-of-the-Art.

Starting point and expected development at the end of the project



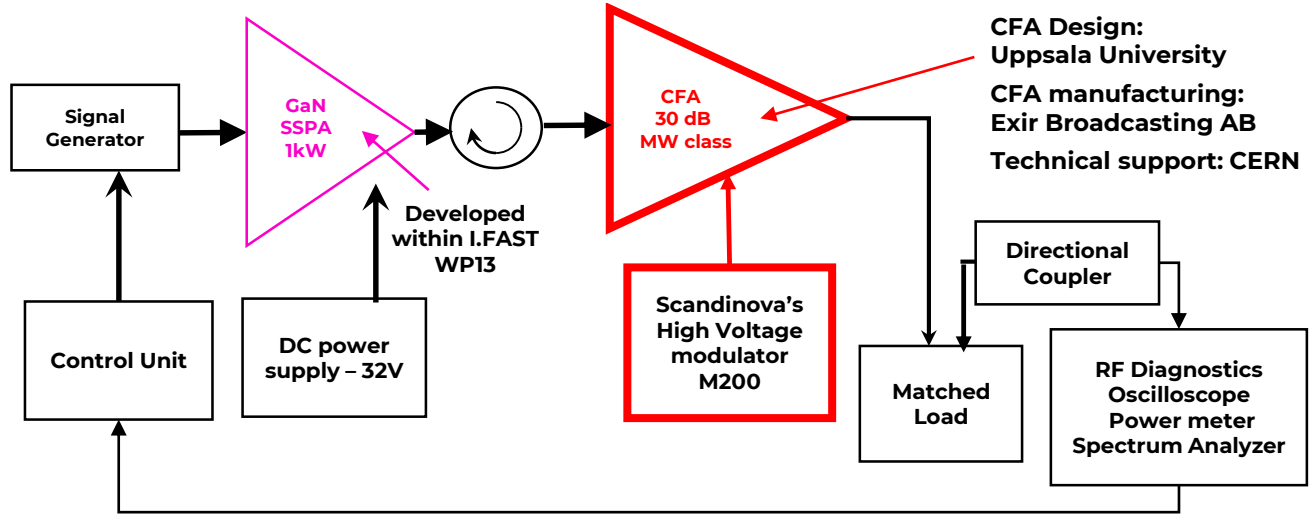
750 MHz GaN amplifier developed in I.FAST WP13



Measured output power of 205 W possible, with a signal gain of 17 dB and an efficiency of 84% in compression. This will be further combined till kilowatt level.

Pout = 53 dBm (60 dBm with combiner) / PAE = 84% @ 750 MHz

Block Diagram of new SSPA driven CFA



- **The current status of the CFA technology is that most of the research was done before solid state power amplifier (SSPA) were available as driver.**

CFA Desired Goals
Peak RF power 1 MW at 750 MHz
Efficiency >80%, Gain ~30dB
Duty cycle 0.1 % and PRF 1 kHz

Furthermore, a very few research is available in public domain.

	Frequency / Lab	Author / Year	Output power / Gain / Efficiency	Application & Remarks
1.	3 GHz - S-band	Thomas Ruden	1.5 MW	For particle accelerator
			13 dB	Water cooling
	Raytheon Company	1965 [1]	>70 %	>10000 hours Life
2.	11.4 GHz X-band	**Eppley *et al.***	300 MW	In linear collider and particle accelerator, experimental Max power 30 MW is achieved as the arching occurred above 100kV. Also inaccurate prediction of cold frequency
			17 dB	
	SLAC	**1992** [2]	65 %	

Milestones and Deliverables: Work Plan

Deliverable (D)/ Milestone(M)	Month
D1 - Design reports, Particle in Cell codes	Sixth (6th)
a) Design of Slow Wave Structures, RF propagation study and its interactions to e-beam using PIC codes b) Magnetostatic design and simulation, development of pulse power diagnostic system	
M1 - CFA design ready for manufacturing	
D2 - Development of SSPA and CFA amplifier including RF subsystems	Eighteenth (18th)
a) Feasibility study using cold test and beam wave interaction testing of non-process tube with cold cathodes b) Implementation of design correction and countermeasure, if any mismatch c) Assembling of tube, processing and Device prototype testing d) Matched rf amplifier prototype incl. versatile control	
M2 - SSPA unit with CFA and Power supply unit ready	
D3 –Testing Reports and demonstration of operational usage and demonstration of phase coherence and high power	Twenty fourth (24th)
a) Development of SSPA driven CFA based RF system b) Testing of RF system and implementation of diagnostic strategies	
M3 - System commissioning and Innovation Pilot demonstrated	**Desired Goals** **Peak RF power 1 MW** **Efficiency >80%, Gain ~30dB** **Duty cycle 0.1 % and PRF 1 kHz**

Resources and budget

Funded by I.FAST : 200 k€

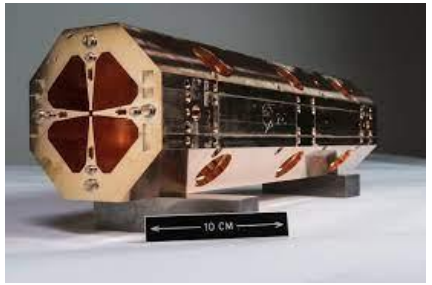
- **Research personnel salaries: 140 k€**
  To undertake the scientific and technical development of the idea a Postdoctoral researcher will be hired at 80% occupancy during two years. The salary cost is evaluated at 130 k€ and 10 k€ are reserved for travel costs .
- **Equipment: 50k€**
  - Oxide-coated cathode CPI Y-646 - 6 k€
  - Vacuum pump - 12 k€
  - CFA manufacturing including material - 15 k€
  - Waveguides - 2 k€
  - Diagnostic instruments - 5k€
  - RF window 1.5 k€
  - Magnets and pole pieces - 1.5 k€
  - Operational costs using existing infrastructure, e.g. furnace - 7 k€
- **Intellectual property (IP): 10 k€**
  - patentability search

In addition, two Researchers at FREIA, funded by **two Marie Skłodowska-Curie Individual Fellowship Actions** will participate to this project:

- **Dr. Alireza Mohadeskasaei**, with an Individual fellowship Grant 2021 entitled: “Green SSPA”
- **Dr. Anshu Singh** with a an Individual fellowship Grant 2022 entitled: “Micro-magnetron”

Potential development and impacts for accelerator sustainability: Particle Therapy Market

- Particle Therapy Market Outlook 2031
- The global particle therapy market was valued at US$ 560.3 Mn in 2021
- Global market projected to expand at 8.6% from 2022 to 2031 to 1.2 Bn by 2031



RFQ medical accelerator development at CERN.

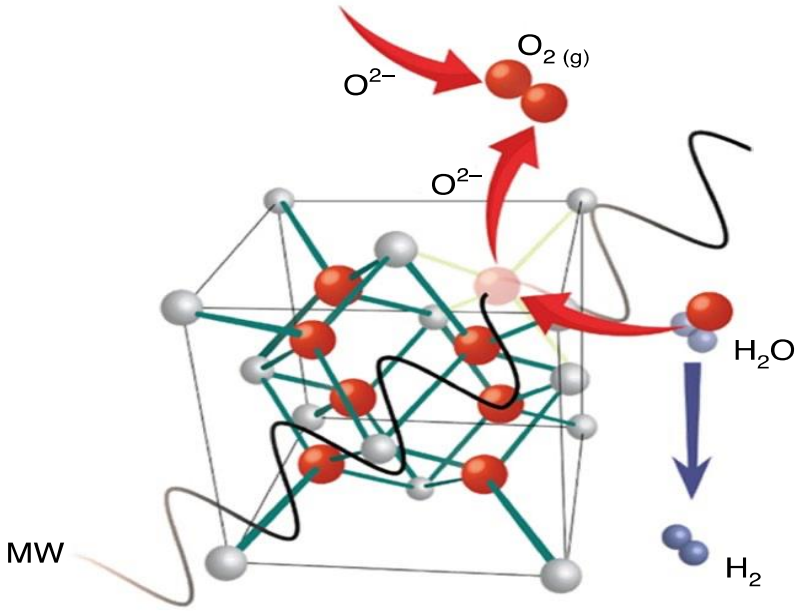
ENEFRF Eurostars project
Collaboration UU and GE Healthcare on new RF power sources for radioisotopes production. Cyclotron worldwide production in Uppsala. CERN's 750 MHz RFQ considered as a viable alternative.

GE Healthcare

iFAST

eurostars™

Potential development and impacts for accelerator sustainability: Hydrogen production



Schematics of H2O reduction into H2 gas through extraction of one O atom by electromagnetic fields at microwave frequencies.*

- Microwave-Assisted Green Hydrogen Production
- There is a potential to generate green hydrogen with a target production efficiency of 35 kWh/kg, which represents a 30% improvement over the current state of the art of 50 kWh/kg, rising efficiency from 67% to 95%.

*Serra, J. M. et al. Nat. Energy https://doi.org/10.1038/s41560-020-00720-6 (2020).

Contact information

Primary Contact

NAME: Dr. Dragos Dancila

TITLE: Associate Professor

MOBILE:+46723663180

E-MAIL: Dragos.Dancila@angstrom.uu.se

WEBSITE: https://www.physics.uu.se/forskning/freia/

SOCIAL MEDIA: https://katalog.uu.se/empinfo/?id=N11-2113

UPPSALA UNIVERSITET

iFAST