Status of the turbine concept for relativistic electron coolers

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Presenting work by I. Alexander, J. Dietrich, A. Hofmann, E. Riehn (HIM)
and Group of V.V. Parkhomchuk, V. Reva at BINP
- Introduction: Accelerator research at HIM
- Turbine operation
- BINP/HIM Prototype
- Near and far future extension plans
- A joint venture between University Mainz & GSI
- Founded 2009...
- Scientific focus: Physics which can be performed at GSI& FAIR
- HIM-Sections: (1) Hadron-spectroscopy, (2) Hadron-structure (PANDA) (3) Theory (e.g. lattice QCD) (4,5) Super-Heavy Elements (two sections: chemistry&physics) (6) Matter & Antimatter
- And last but not least: (7) Accelerators and integrated detectors
Objectives of HIM-section

Accelerators and integrated detectors (ACID) (est. 2009)

1. FAIR: HESR-Cooler support: Beyond 2MV:→4-8MV

2. Provide accelerator solutions for SHE research by GSI and JGU groups: low beta SRF ion accelerator cavities
• ACID cooler group does R&D on small, well defined aspects related to the design of relativistic magnetized coolers

• Such small scale research is well adapted to the possibilities of HIM (somewhat in between university research and „big science“)

• Ongoing projects: turbines as power generators for higher voltages >2MV (Poster by I. Alexander)

• Test set-ups for collector optimization & control, non invasive beam diagnostics (Poster by Th. Beiser)
How to power solenoid channel & terminal?

- More cooling power needed due to stronger beam/target interaction
  → Magnetization of beam required!
- Powering of continuous solenoid channel in d.c. acceleration stage
- Powering of terminal – electronics, source/collector
- Power requirement 50kW or more for supply floating at U>2MV

Conventional solutions: transformer/insulating shaft: May become cumbersome or even unfeasible under these conditions
- Use of “turbogenerators” (gas/steam turbine + electrical generator?)
Solenoids must be powered by floating power supply (e.g. isolated turbogenerator)

- **Not realized** for Jülich 2MV-cooler…
- 19th century technology – but still requires mechanical systems engineering & quality control → commercial product should be reliable

First idea for Jülich Cooler
~600 W Turbogen. Powering 60kV + solenoids

5kW Turbogenerators (company: DEPRAG, product name „green energy turbine“) have been purchased
- Ball bearings (2014)
- Gas bearings (2017)
The turbine approach

- Standard screw compressor generates pressurized medium (dry air or others)
- Guided into pressurized HV-tank (insulating pipes in tank)
- Gas expands in turbine and is redirected to compressor inlet
Test set – up for long term operation at HIM/Mainz

(Compressor not visible)
Test Results

- Turbine operated > 1000 hours without failure or relevant wear of bearing at 5kW
- Lubrication of bearings is needed, but minimal (remotely controlled, <0.1 cm³ once in 1000 hours)
- Test of turbine (& lubrication unit) in 10 bar pressurized vessel successful
- Turbine with gas bearings delivered in summer 2017, test pending
Thermal considerations

- Cooling of compressed gas reduces efficiency.
- But then, exhaust gas is also cooled due to adiabatic expansion which helps dealing with heat generated by loads inside HV-tank.
- Estimated efficiency: 5kW floating power from 30kW (wall plug).
- Compressor wall plug requirement for 8MV HESR cooler would be large (~500kW), but not impractical.
- BINP/HIM contract for fabrication of „prototype“ module
- 5kW turbogenerator integrated into prototype
- turbine powers solenoid on terminal and 600kV d.c. Power supply
- delivery planned spring 2018
- Tests foreseen in HIM experimental hall - Module in pressure vessel (dry air or nitrogen as fluid and insulation gas)
Module status

- Operated at 100kV in air
- Final assembly and testing without pressure vessel at BINP
- Pressure vessel under design at HIM
- Installation and system test planned at HIM spring in 2018
Near (and far) future extension plans
The 600kV device should be scalable...

but reliable electron beam operation should be demonstrated first...

What can be done within the given limitations?
Near (and far) future extension plans

I. Alexander

status end of 2018

- pressure vessel
- solenoid
- turbine

- 600 kV
- commissioning of HV module
- powering the solenoid at HV

first possibility

- pressure vessel
- electron gun (new)
- beam diagnostic (new)

- install a gun and beam diagnostic
- further parameter characterization

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Near (and far) future extension plans

**Second possibility**
- Install a 2nd HV module
- Increase potential to 1.2 MV
- Further parameter characterization

**Third possibility**
- Install necessary solenoids
- Install beam recirculation
- Produce high electron current
- Check if all parts work together

 Beam recirculation (new)
Conclusion

- Turbines are qualified as floating power generator for electron coolers
- BINP produces turbine driven HV-Generator for 600 kV+ several kW of power on terminal
- Extensive testing at HIM planned beginning 2018
- Extension towards real electron beam operation will follow
- Qualified system will be scalable towards HESR energies
Thank you!