### NON-LINEAR BEAM EXPANDER SYSTEMS IN HIGH-POWER ACCELERATOR FACILITIES

Søren Pape Møller

26RD & 27TH MARCH

Welcome, AU, ASTRID2, Programme

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### AARHUS UNIVERSITY, DENMARK

> ~40.000 students
> ~11.000 staff (~6.500 academic, ~4.500 tech/adm.)

- > Budget 800 M€
- > Established in 1928
- > 2<sup>nd</sup> largest university in Denmark
- > Has all the standard academic areas
- > Merged with
  - Aarhus School of Business and Engineering College of Aarhus



#### DEPARTMENT OF PHYSICS AND ASTRONOMY

- >~100 students/year
- >~100 staff (~50 academic, ~50 tech/adm.)
- > Established in 1933 (for teaching medical students)
- Part of Faculty of Science and Technology (from 1954)
   Main research areas
  - > Atomic, molecular and optical (AMO) physics
  - Condensed matter physics and nanophysics, surface physics, statistical physics and biophysics
  - > Subatomic physics
  - Astrophysics and cosmology



#### **INSTITUTE FOR STORAGE RING FACILITIES (ISA)**

- >~10 staff +
- Operate and develop the synchrotron ASTRID and ASTRID2
- Other accelerator projects: ELISA (electrostatic storage ring for ions) several other small electrostatic accelerators and storage rings
- Involvement in: DANFYSIK projects PT ESS





#### NON-LINEAR BEAM EXPANDER SYSTEMS IN HIGH-POWER ACCELERATOR FACILITIES

>Ways of reducing peak current density, while respecting footprint

- Related issues are: HEBT – tails of beam - Losses – apertures – collimators
   magnets - radiation resistant materials – handling of radioactive components - interfacing to target target
- > Apologies for emphasizing the ESS



### WORKSHOP PROGRAMME

- > Monday 26th March 2012
- > 09:00 09:20 Welcome, programme and practical information Søren Pape Møller, ISA
- ``
- > Session 1 Chair: Phu Anh Phi Nghiem
- > 09:20 09:35 Introduction to ESS Håkan Danared, ESS
- > 09:35 10:00 The particle distribution at the end of the ESS linac Ryoichi Miyamoto, ESS
- > 10:00 10:40 Generating uniform beam distributions at the target Nicolaos Tsoupas, BNL
- > 10:40 11:00 Tea/Coffee break
- > 11:00 11:40 The LANSCE area-C experiment Barbara Blind, LANL
- > 11:40 12:20 Development of a beam flattening system at J-PARC/JSNS Shin-ichiro Meigo, JPARC
- > 12:20 13:00 The high energy beam transport and expander design at the China Spallation Neutron Source Weibin Liu (Accelerator Center, Institute of High Energy Physics, Beijing, China)
- > 13:00 14:00 Lunch
- >
- > Session 2 Chair: Søren Pape Møller
- > 14:00 14:40 IFMIF high energy beam line design and beam expansion using non-linear multipole lenses Nicolas Chauvin - CEA-Saclay, France
- > 14:40 15:20 Status of the beam expander system for the European Spalation Source Anne Holm, ISA
- > 15:20 15:40 Tea/Coffee break
- >
- > 15:40 16:20 The ESS target and wishes for the beam expansion seen from the target side Pascal Sabbagh, ESS
- > 16:20 17:00 Limitations for the ESS HEBT magnets: high radiation and large apertures Franz Bødker, Danfysik, Denmark)
- > 17:00 A tour around ASTRID/ASTRID2 with BEER
- >
- > 18:10 Transfer to Varna Palæet for dinner
- >



### WORKSHOP PROGRAMME

>	Tuesday 27th March 2012	
>		

- > Session 3 Chair: Andreas Jansson
- > 09:00 09:40 Accelerator to target interface problems with high power beams Jingyu Tang - (Accelerator Center, Institute of High Energy Physics, Beijing, China)
- > 09:40 10:20 Beam transfer line for the MYRRHA project. Beam on target for SPIRAL2 Luc Perrot – (CNRS/IN2P3, France)
- > 10:20 10:40 Tea/Coffee break
- >

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- > 10:40 11:20 Impact on the IFMIF irradiation property from the beam profile, Keitaro Kondo - (KIT, Karlsruhe, Germany)
- > 11:20 12:00 Target spot diagnostics for SNS and ESS Tom Shea, ESS and SNS
- > 12:00 13:00 Lunch
- >
- > Session 4 Chair: Chris Prior
- > 13:00 14:30 Discussion and concluding remarks
- >
- > 14:30 Meeting ends, participants depart or ...



## DISCUSSION SESSION

- 1. How do we balance peak-current density versus beam power in tails / on fixed collimator?
- 2. What aperture in magnets should we choose? How much contingency should we add for aperture
- 3. Which expander systems should we choose for low and high-emittance beams, respectively? E.g. ESS vs. SNS beams?
- 4. Are collimators useful in beamlines? For rings? For Linacs? Fixed or movable? What powers are reasonable/acceptable?



#### ISA

- > ASTRID is operating ~40 weeks/year, 24 hours/day, 7 days/week
- >~150 users annually, 50/25/25 % from abroad/Aarhus/DK
- FUNDING for **ASTRID2** 37 MDKK (5 M€) 08/2009-02/2013: •ASTRID modifications (mainly fast extr. kicker)
- •Transfer beamline
- •ASTRID2
- •2T MPW
- •Smaller SR beamline modifications/upgrades

10 MDKK for AMOLINE (incl. U-53) Future (X-mas): Materials/iNANO/STM beamline



### ASTRID2

#### >Dec 2008: 37 Mkr

- > Build a new SR light source
- > Convert ASTRID into a booster
- > Move existing beam lines
  - > New 2 T Multi Pole Wiggler
- > Project runs 2009-2013
- > 2011: 10 Mkr
- > AMOLINE, incl. undulator U-53
- > Future:

> Materials/STM/iNANO beamline



ASTRID2 Søren Pape Møller





### WHY ASTRID2

- >Better machine
- > Smaller emittance (smaller beam sizes)
- > Constant intensity (frequent small refills (Top-up))
- > Better stability
  - Better orbit control
  - Smaller temperature drift
- >Beamlines
- More insertion devicesLonger beamlines





- > -2010 normal ASTRID operation with SR
- > 2011 install ASTRID2
- > 2012 Commission ASTRID2 and first beamline
- > 2013 ASTRID2 operating in full including all beamlines





### ASTRID VS. ASTRID2

Parameter	ASTRID2	ASTRID
Energy	580 MeV	580 MeV
Circumference	45.7 m	40.0 m
Current	200 mA	200 mA
Lifetime	Top-up (~few hours)	~100 hours
Horizontal emittance	~10 nm	140 nm
Vertical Emittance	0.5 nm	7 nm
Characteristic energy Dipole/MPW	0.24/0.45 keV	0.36 keV
Characteristic wavelength	5.2/2.8 nm	3.5 nm
Straight sections (number and length)	4×3.0 m	1×2.0 m
Harmonic number (bunches)	16	14



#### **BEAM EMITTANCE - SOURCE SIZE**



Diffractionlimit  $\sigma_{R'} = \frac{\lambda}{4\pi} = 10 \, nmrad \text{ at } 10 \, eV \, (125 \, nm)$ 

> The light from ASTRID2 is diffraction limited horizontally for all photon energies below ~10 eV and vertically basically for all photon energies



### **ASTRID-ASTRID2 COMPARISON**



Brilliance: Number of photons per second, on a small spot, after a monochromator



March 26<sup>th</sup> 2012

### **INSERTION DEVICES FOR ASTRID2**

- 1. ASTRID U55, 0.56 T, 48 poles
- 2. New W116, 2 T, 14 poles
- 3. New U53, 1.06 T, 87 poles, ordered from KYMA for AMO beamline











March 26<sup>th</sup> 2012

### **ASTRID2 INSTALLATION**

#### Jan. 2011

#### Mar. 2011



#### Mar. 2012



# STATUS



AARHUS

INIVERSITET

- > 5 girders baked and last girder being baked now
- > Injection straight and RF straight will follow soon

#### >Power supplies and cables

- > All large power supplies installed
- > First corrector power supplies will be ready in ~1 week
- > Most cables are installed

#### >Commissioning

- > First part of transfer beamline has been commissioned
- Expect to begin commissioning in the ASTRID2 hall in May
- > Missing
- > BPM
- > RF cavity









#### March 26<sup>th</sup> 2012

### ASTRID2 105 MHz CU CAVITY





105 MHz (h=16) 8 kW solid-state amplifier



### **ASTRID EXTRACTION**





### ASTRID USERS 2008-2011





### REMINDERS

- •Presentations to Heine before session
- •Hotel names before lunch for taxis tonight
- •Please leave time for discussions!