All-permanent magnet ECR plasma for EUV light

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ABSTRACT

ECR plasmas are widely used in ion sources to produce a wide range of ion species : from H^+ to U^{50+}

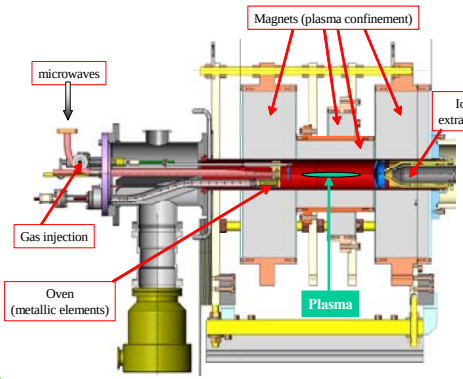
The so called "Electron Cyclotron Resonance Ion Sources (ECRIS)" are installed in major particle accelerators in the world.

13.5 nm photons are obtained by deexcitation of multiply charged ions like Xe^{10+}

This presentation shows the capability of an ECRIS to be a light source, whatever the wavelength and specially at 13.5 nm.

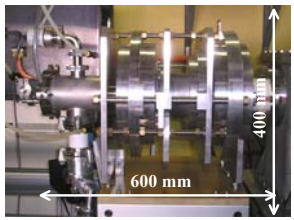
Two ECR photon sources with good brightness at 13.5 nm are proposed.

An ECR Ion Source is a magnetically confined plasma



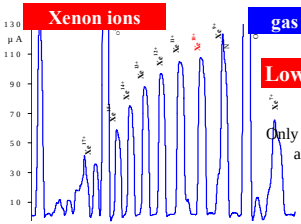
no cathode, no filament : infinite lifetime

ECRIS are now used for cancer therapy:
-) at GSI - Darmstadt / Germany
-) at HIMAC - Chiba / Japan
more than 6 months plasma without maintenance



What kind of ions can be produced by ECR Ion Source ?

From H^+ to U^{50+}, e.g. Sn, Te, Sb…



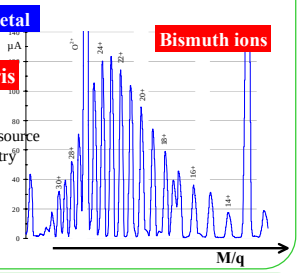
Ion Charge State Distribution when the source is tuned on Xe^{10+}

gas

Low pressure: no debris

Only elements injected into the source are seen by mass spectrometry
No wall contamination

metal



30 years of experience !

CEA has designed ECRIS that have been installed on particle accelerators around the world for atomic and nuclear physics :

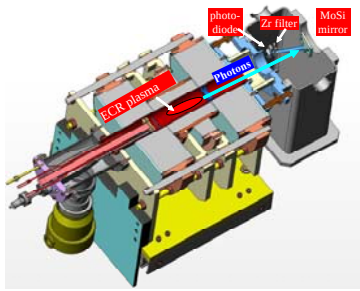
Europe: **CERN**-Geneva (Switzerland), **GSI**-Darmstadt (Germany), **KVI**-Groningen (The Netherlands), **LNS**-Catania (Italy), **Ganil**-Caen (France), **PSI**-Zurich (Switzerland)

USA: **NASA-JPL**, Pasadena - CA, **ORNL**,Oak Ridge - TN, **University of Nevada**, Reno - NV

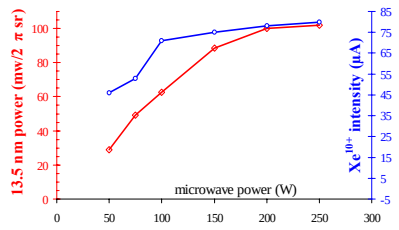
Japan: **RIKEN**-Wako Shi, **RCNP**-Osaka

China: **Institute of Modern Physics**, Lanzhou **South Africa**: **NAC** – Cape Town

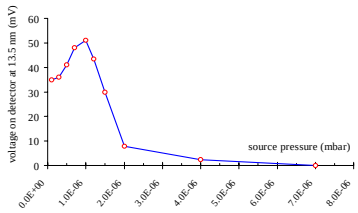
EUV detection: preliminary results with Xe plasma



Top half view of photon detection with ECRIS



Evolution of power at 13.5 nm and Xe^{10+} intensity



Evolution of power at 13.5 nm with gas pressure

Source qualities:

fully CW
low pressure
no debris
very good stability
long lifetime

Origin of 13.5 nm in ECRIS (with Xe plasma):

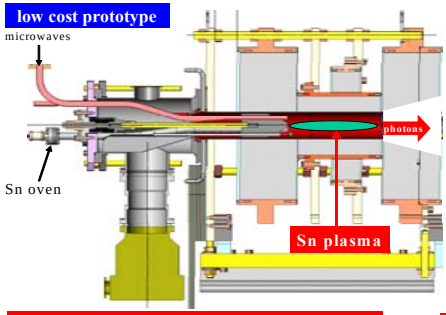
5p-4d line for Xe^{10+}

Excited states of Xe^{10+} are produced by :
Electron impact excitation of Xe^{10+}
Charge exchange of Xe^{11+} with neutrals
Electron capture by Xe^{11+}

How to transform an ECR Ion Source into an EUV light source

Ion extraction suppressed → ions are confined in the photon source
Plasma pinched at photon extraction

low cost prototype



With an all-permanent magnet source the goal is a few Watts in continuous regime @13.5 nm (collected)

With superconducting magnets, the goal is 100W in continuous regime @ 13.5 nm (collected)

Low microwave frequency : 13.5 GHz

Low ion density : $n_i \sim 10^{11} - 10^{12}$ cm^{-3}

High microwave frequency: f > 28 GHz

Higher ion density : $n_i \sim 10^{13} - 10^{14}$ cm^{-3}

References

VUV diagnostic of the plasma of an ECR ion source, M. Druetta, D. Hitz, Journal of Optics 23 (1992) 259.

Fundamental aspects of ECR ion sources : from classical to large superconducting devices (invited), D. Hitz et al., 8th ICIS, Kyoto, 1999, Review of Scientific Instruments, 71 (2000) 839.

Multiply charged ion production with ECR ion sources: state of the art and prospects, D. Hitz et al. Nuclear Instruments and Methods, B205 (2003) 168.

CEA Patents

US5350974; US5336961; US4780642; US4631438; US4580120; US3571734; EP0532411; EP0514255; EP0374011; EP0252845; EP0238397; EP0232651 EP0145586; EP0142414; EP0138642; EP0130907