LEAF-CAP: Laboratory Experiments on Aerosol Formation by Colliding Ablation Plumes

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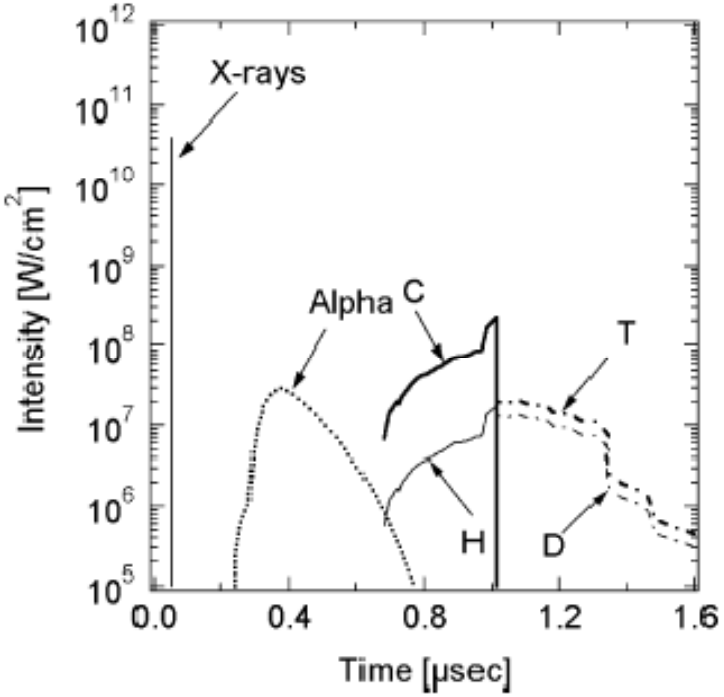
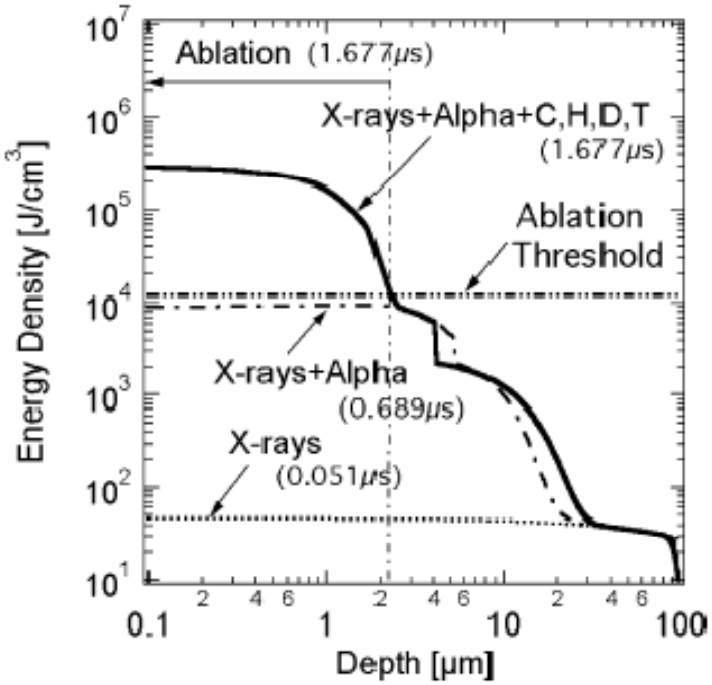
Motivation

- IFE chamber walls will be subjected to the bombardment of high-energy pulse X-ray, unburnt DT, pellet debris generated by implosions.
- Wall materials ablation can lead to the formation of aerosol in the chamber center (or major axis) as well as in the edge region.
- Aerosol particles floating in the chamber center would scatter subsequent laser, affecting pellet implosion performance (i.e., implosion frequency).
- Ablated materials would be re-deposited on the wall if not associated with aerosol formation, both of which affect the wall lifetime.

IFE reactor chamber energetics



Irradiation intensity of the X-rays, alpha particle, carbon, a hydrogen, heavy hydrogen, and tritium ions in the first wall surface in conditions with a nuclear fusion output 400MJ and a chamber radius of 4 m.

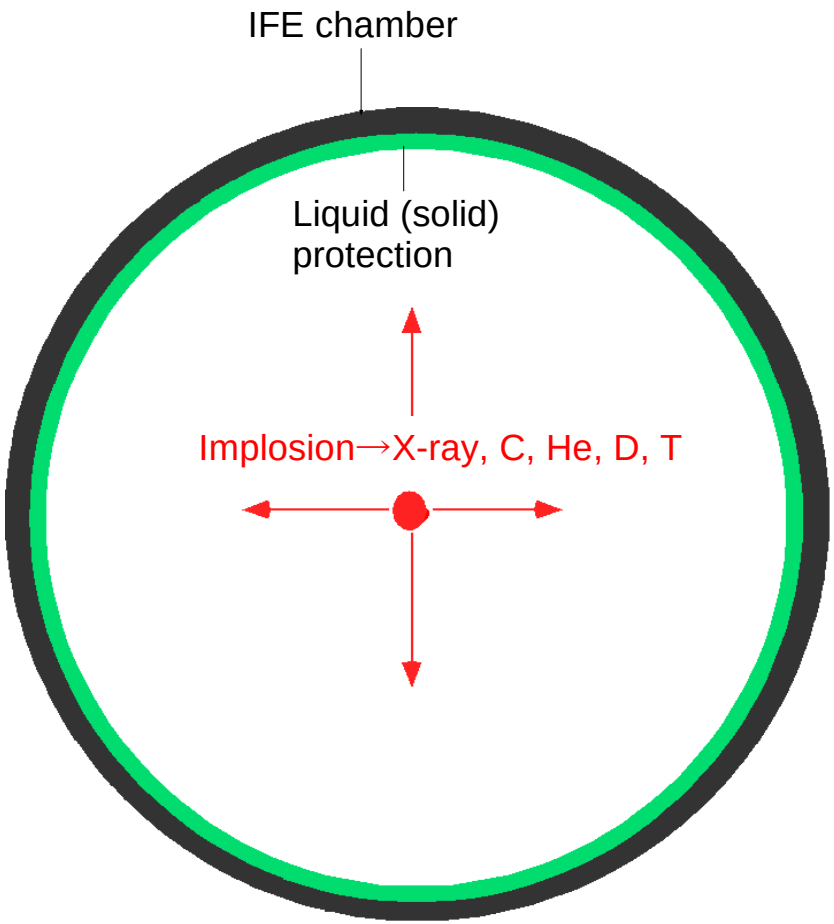


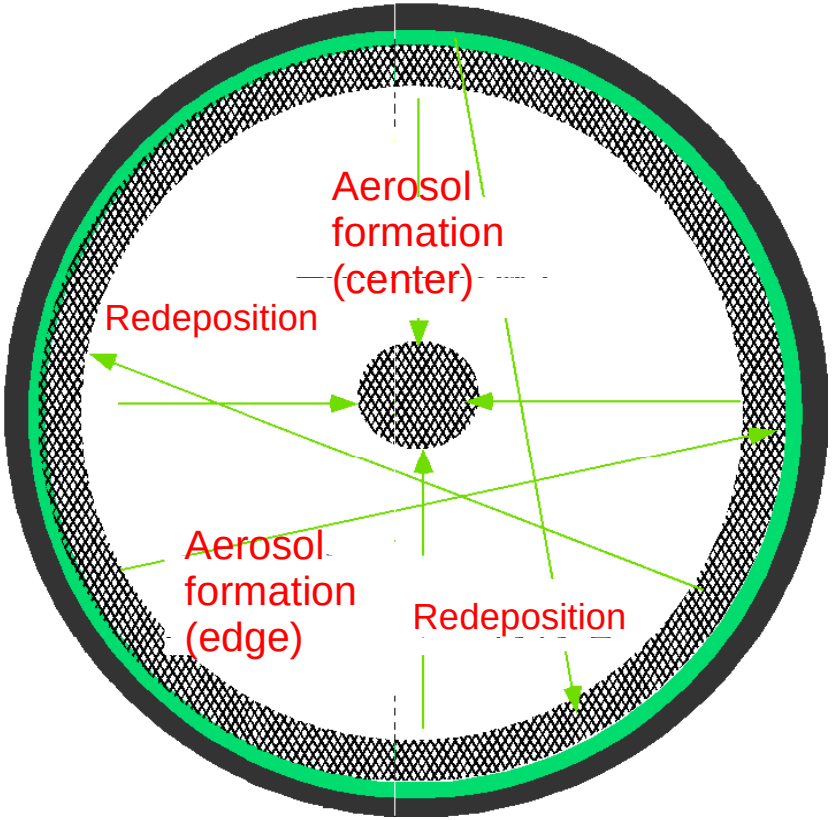
The calculation result of energy deposited on the first wall by the X-rays and charged particles.

After Yamamoto' s PhD thesis (2006)

IFE reactor chamber materials dynamics

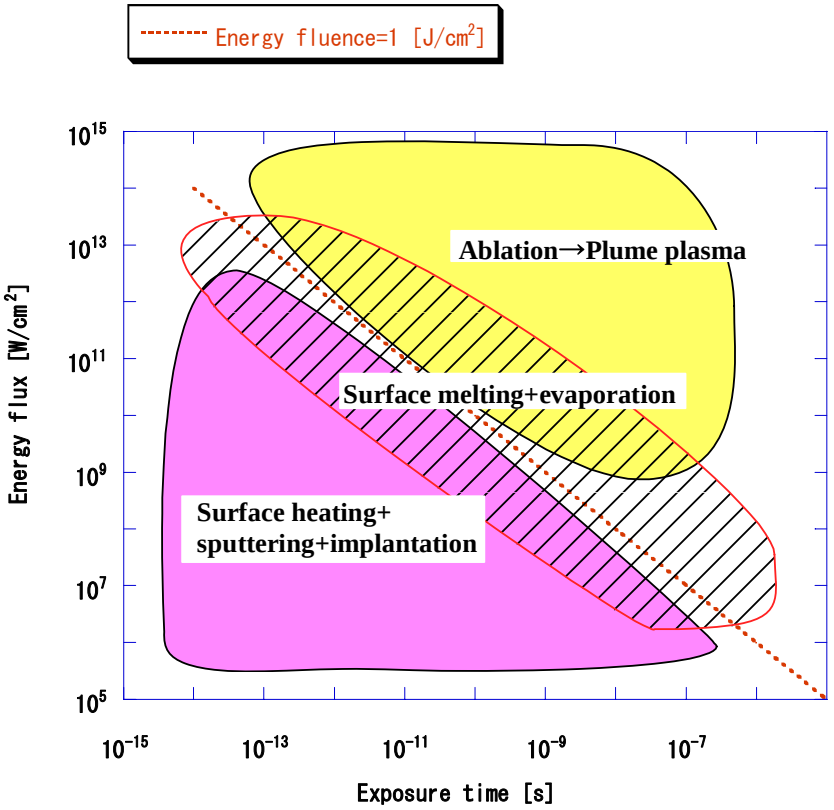
-Ablation and re-condensation affecting the wall lifetime-



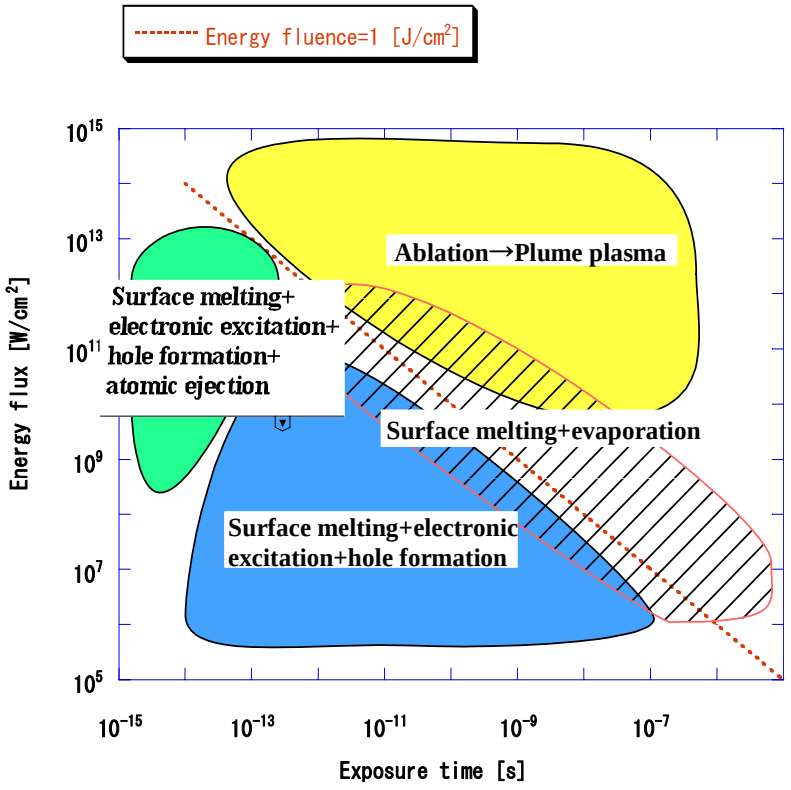


Ion, laser beam-matter interactions

Ion beam-matter



Laser beam-matter



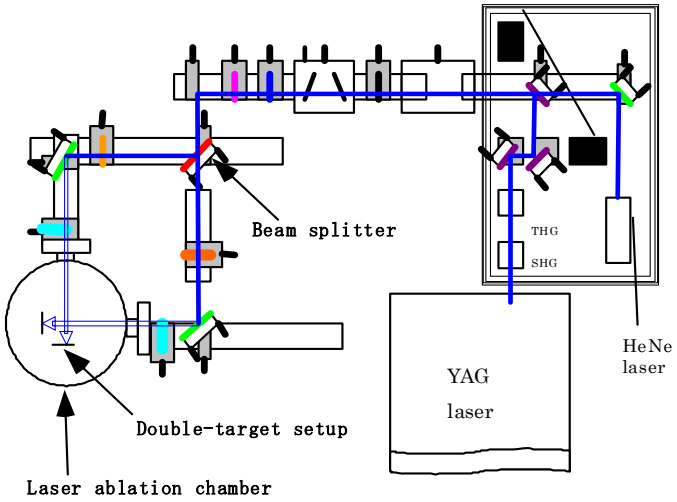
What is the LEAF-CAP exp. ?

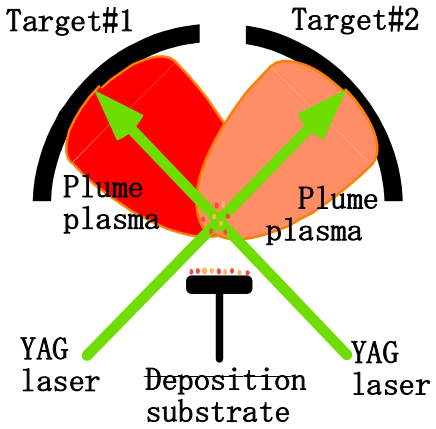
- YAG laser (~1J/6ns-pulse at 10Hz) is first converted into the 3rd harmonic (355nm), so that the absorption by solids is efficient.

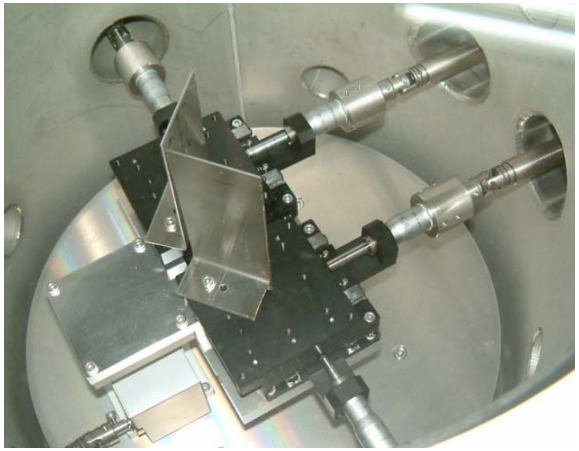
- The converted laser beam will then be split into two beams to irradiate two targets at the same time.

- These targets arced in shape will generate ablation plumes, which will collide each other at the arc center.

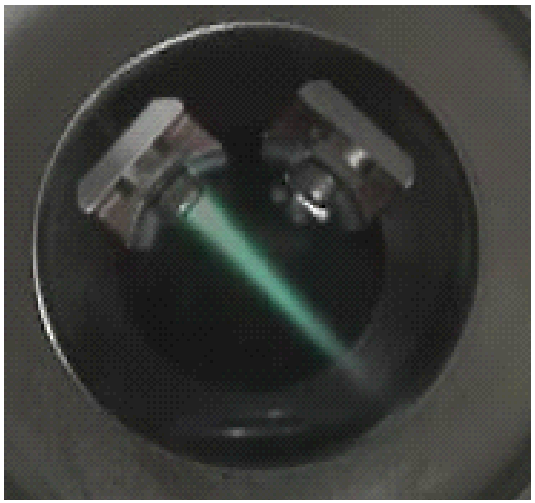
LEAF-CAP : Laboratory Experiments on Aerosol Formation by Colliding Ablation Plumes







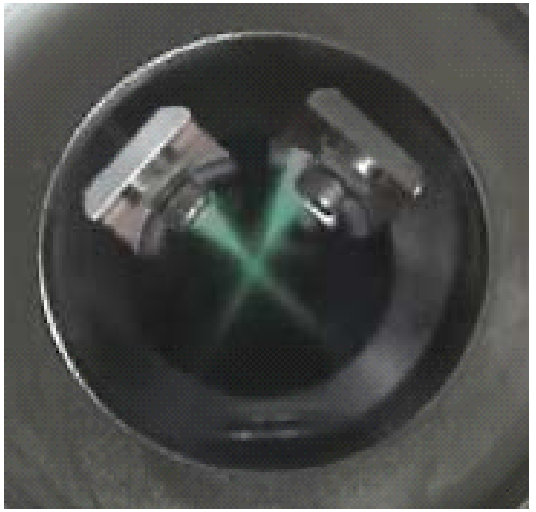
Single and colliding double plumes of Cu



Cu-single plume

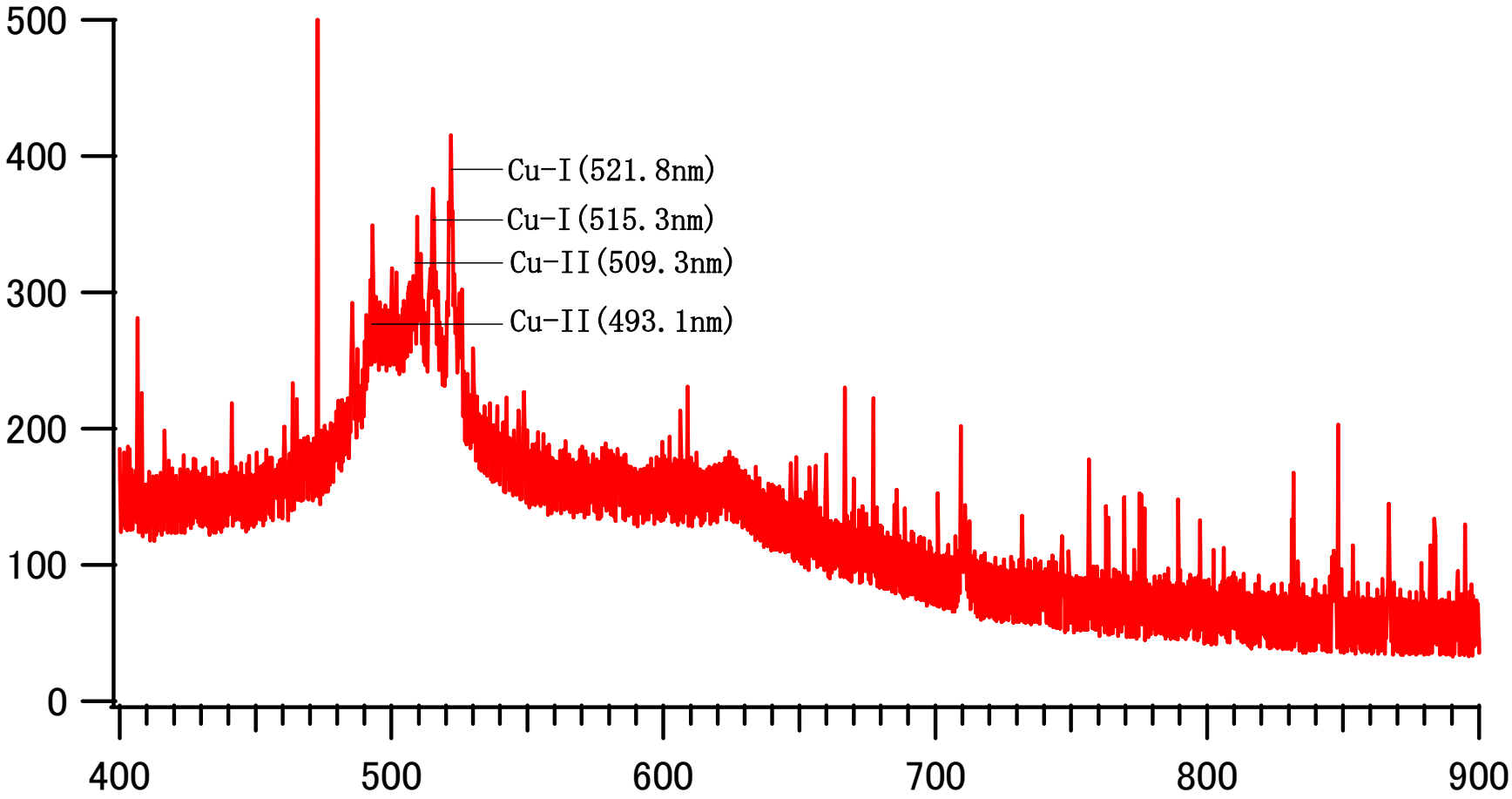
?

?

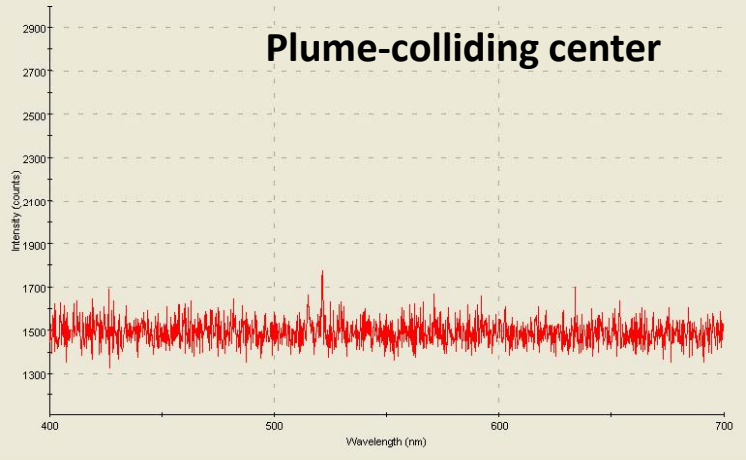


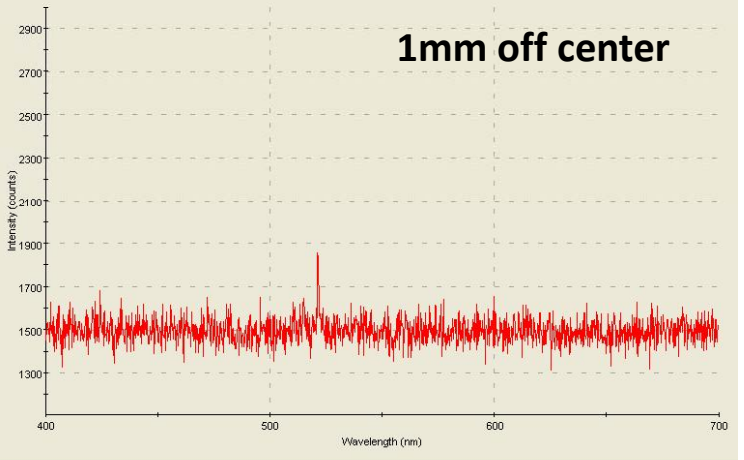
Cu-double plume

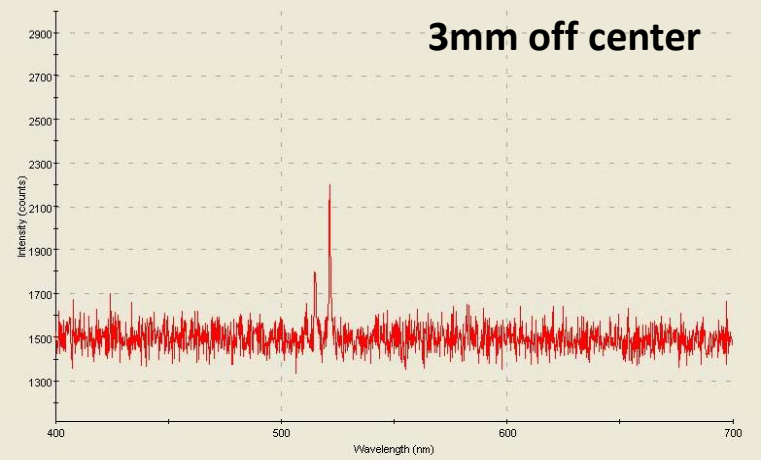
Visible spectroscopy of a single Cu-plume

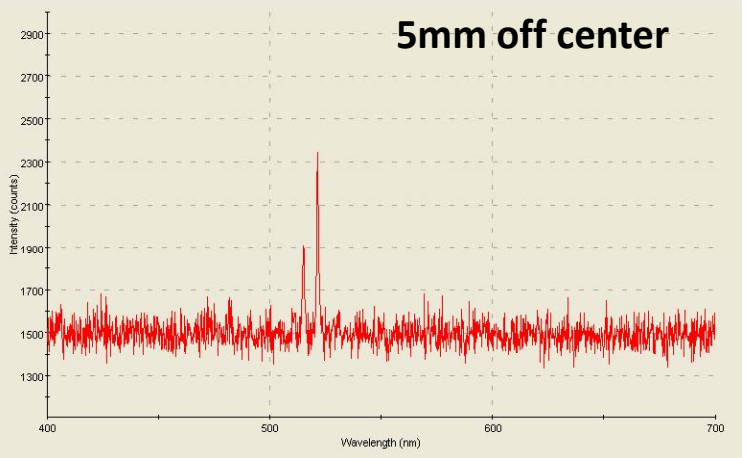


Visible spectroscopy of colliding Cu-plumes









Single and double plumes of C

C-single plume

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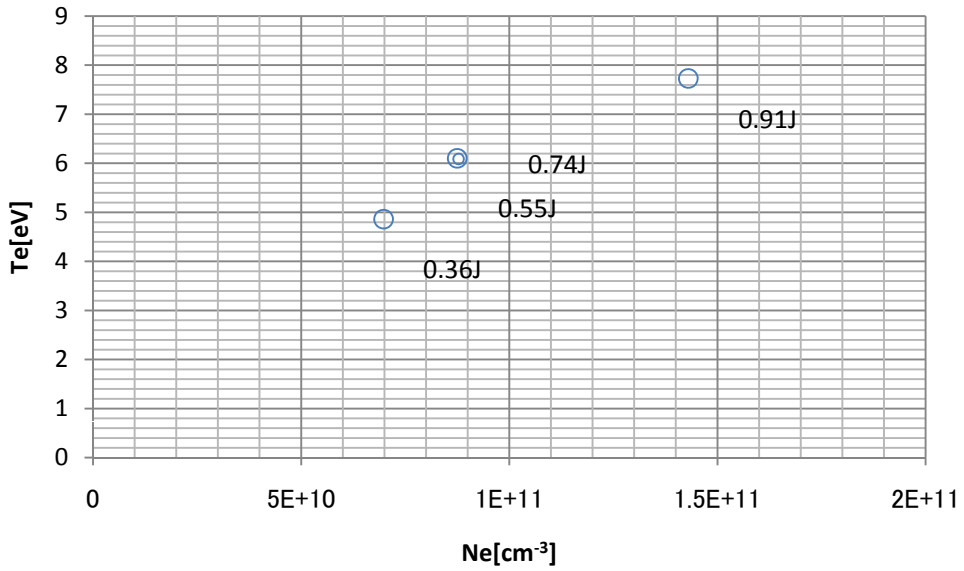
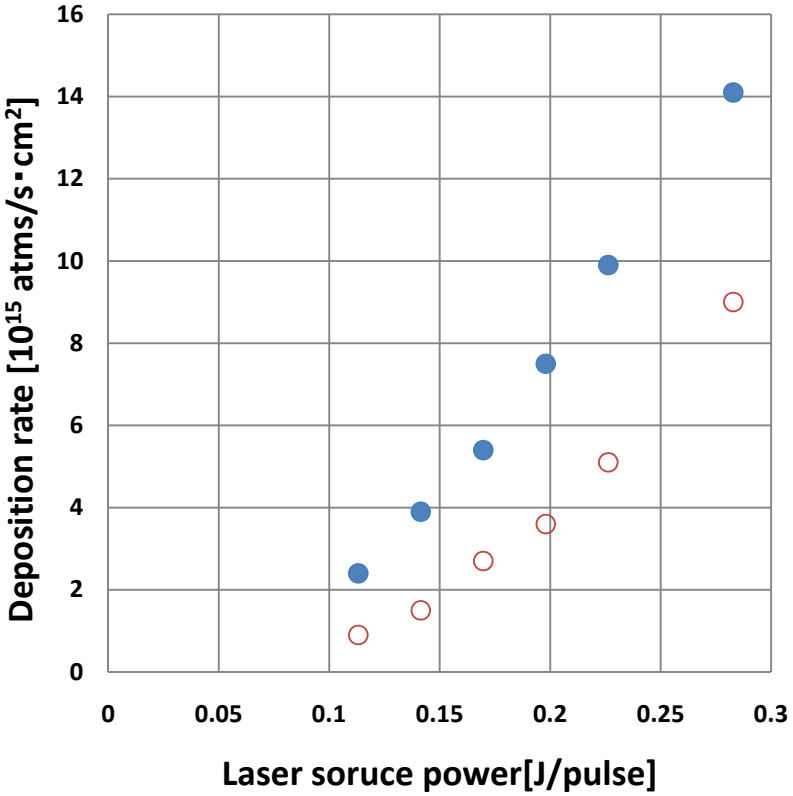
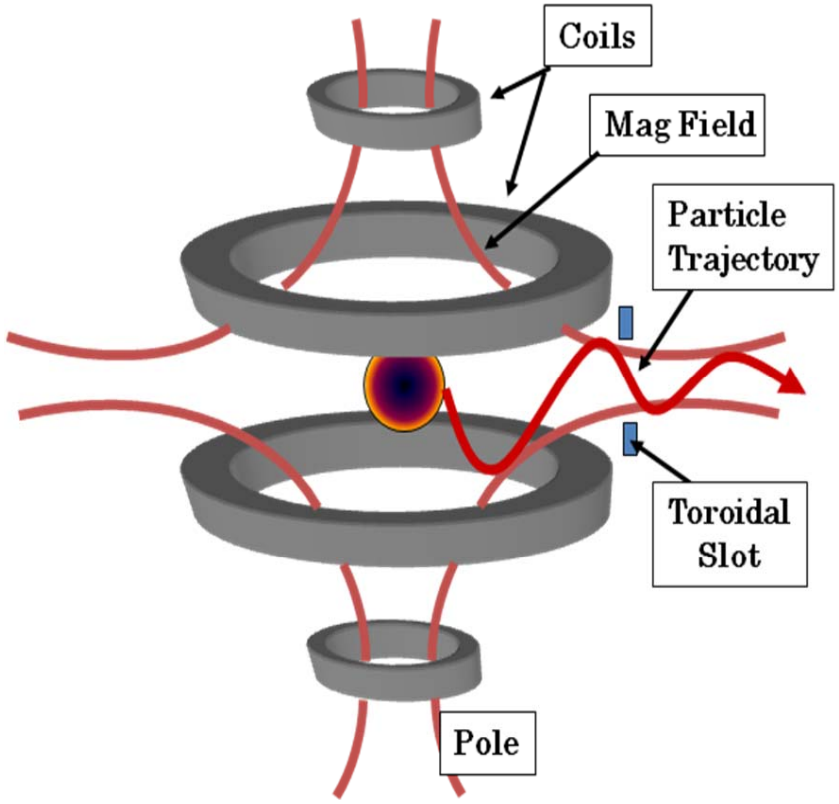
Double plume

Characterization of colliding double plumes of C



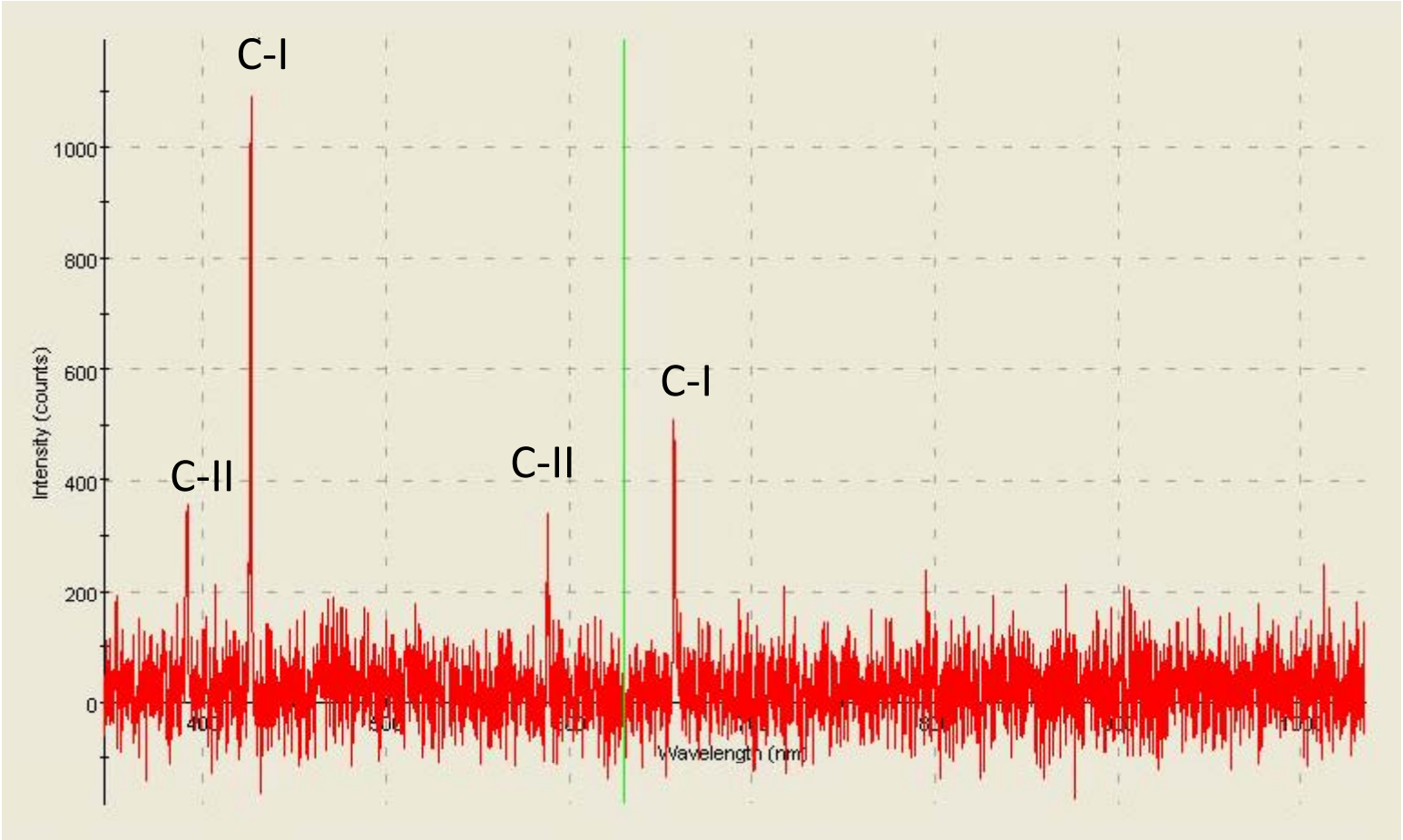
Effects of magnetic deflection



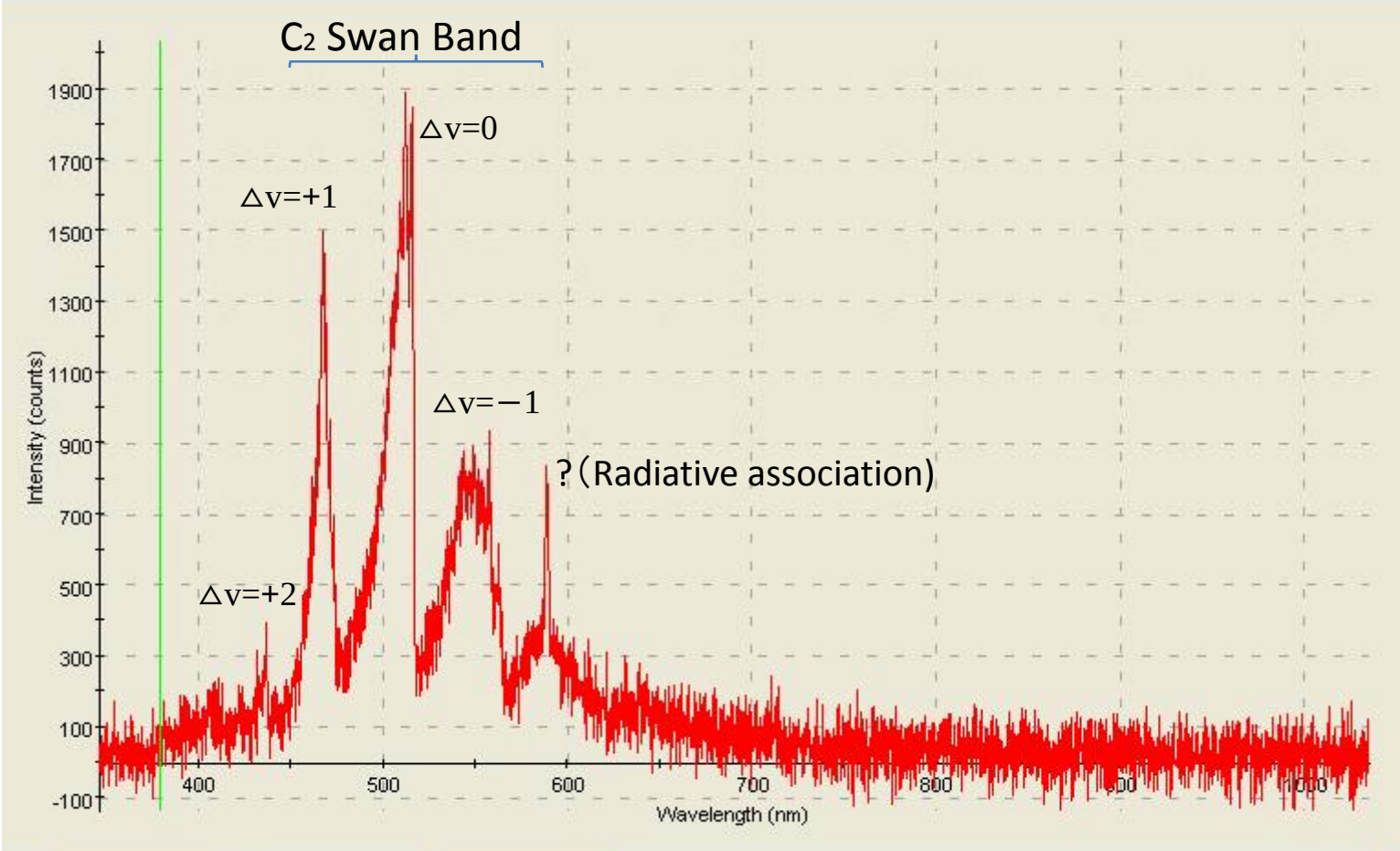


A.E. Robson, "Magnetic Protection of the First Wall," 12 June 2003

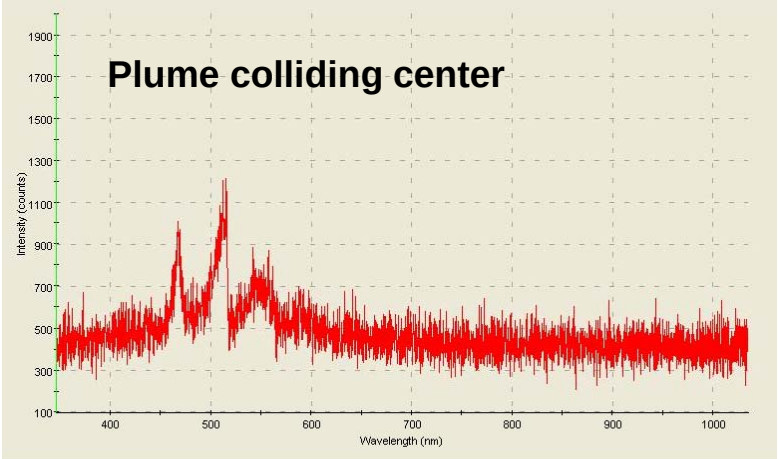
Visible spectroscopy of a single C-plume

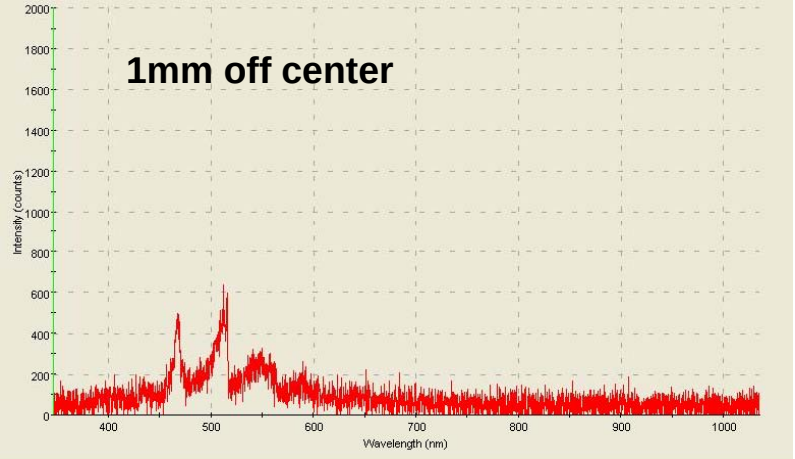


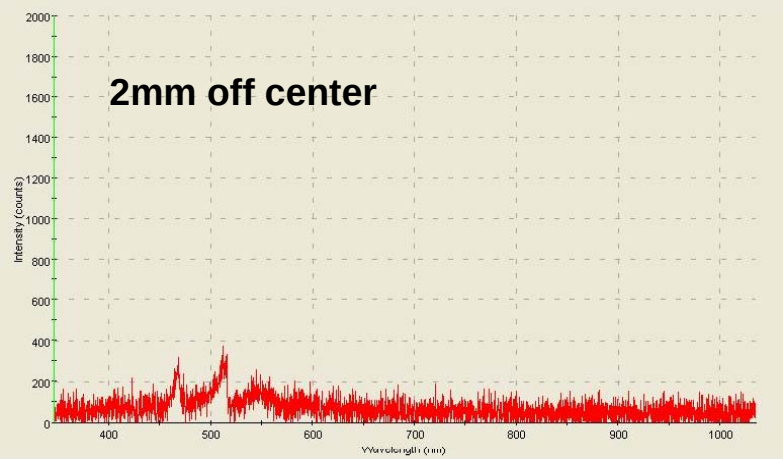
Visible spectroscopy of colliding plumes of C

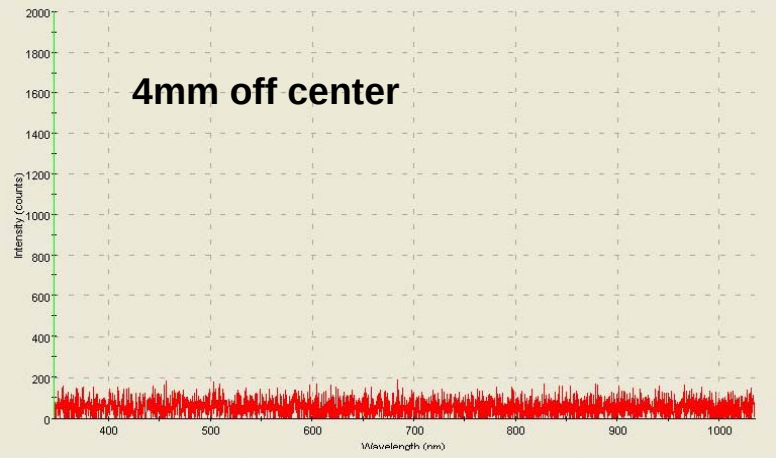


Visible spectroscopy of colliding C-plumes









Possible A&M reactions in LEAF-CAP for Cu and C

- **For Cu-plume collisions:**

$Cu^{(1+)} + e = Cu^{0}$ ▪▪▪ Recombination

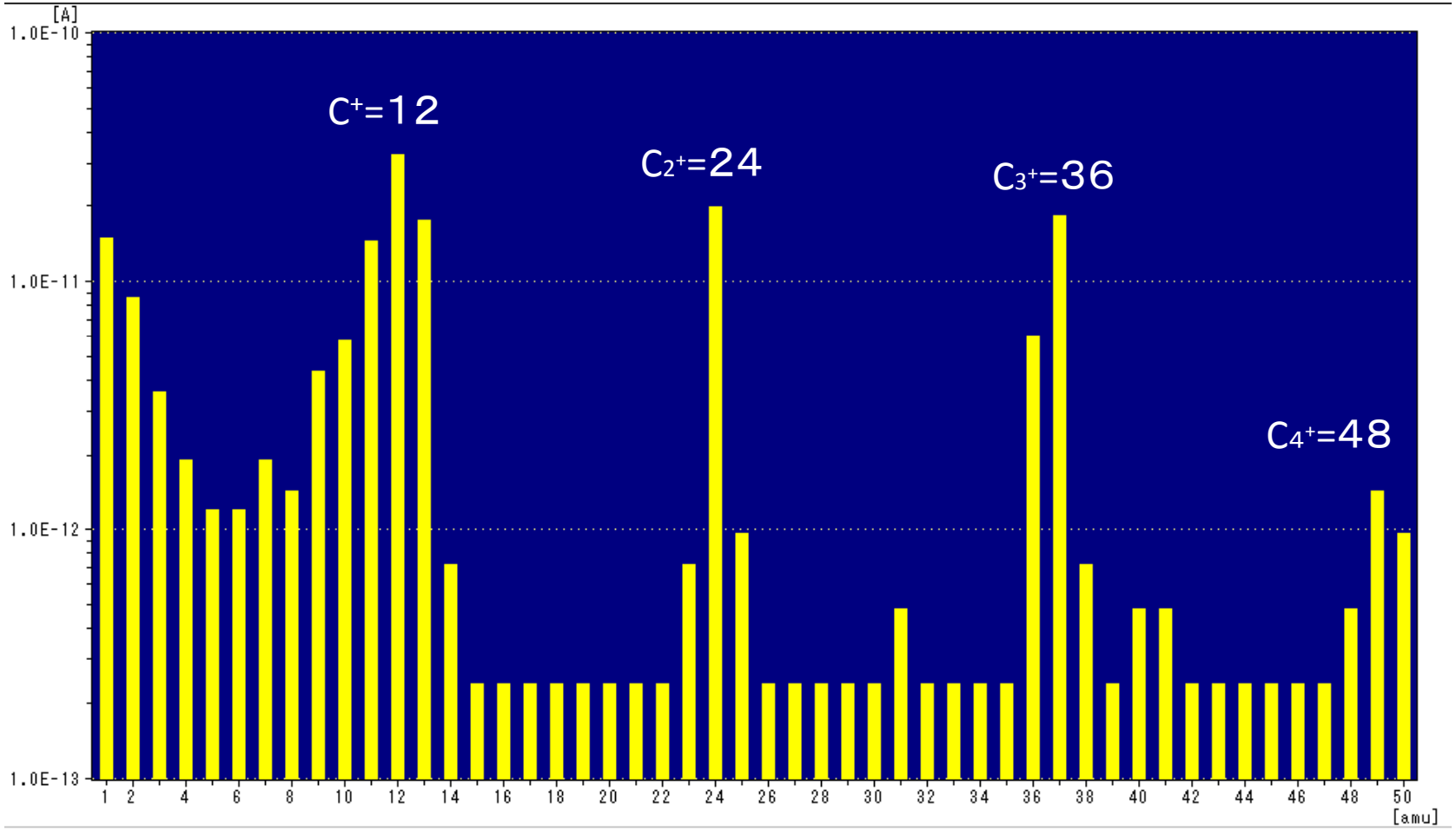
$Cu^{(0^*,\,1+)} + Cu^{(1+,\,0^*)} = Cu_2^{0}$

- **For C-plume collisions:**

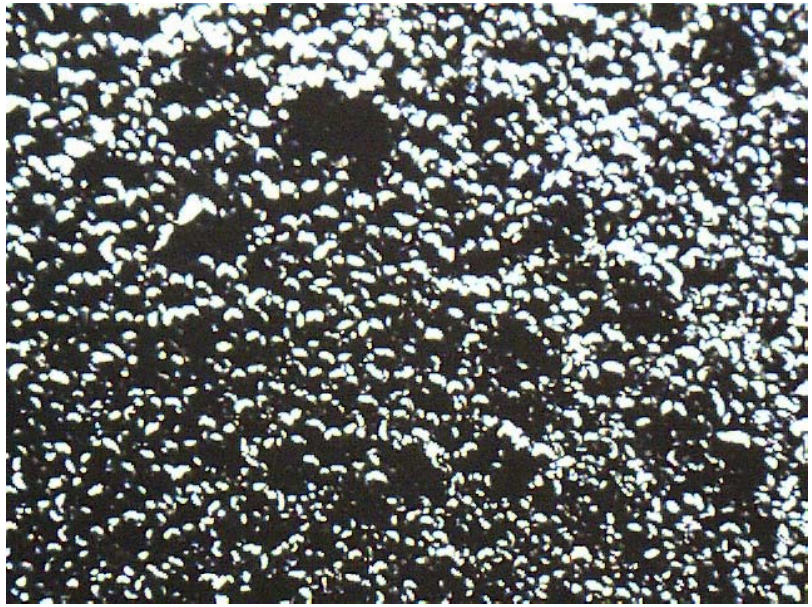
$C^{(0^*,1+)} + C^{(1+,\,0^*)} = 2C^{0^*} = C_2 + h\nu$ ▪▪▪ Rad. Assoc.

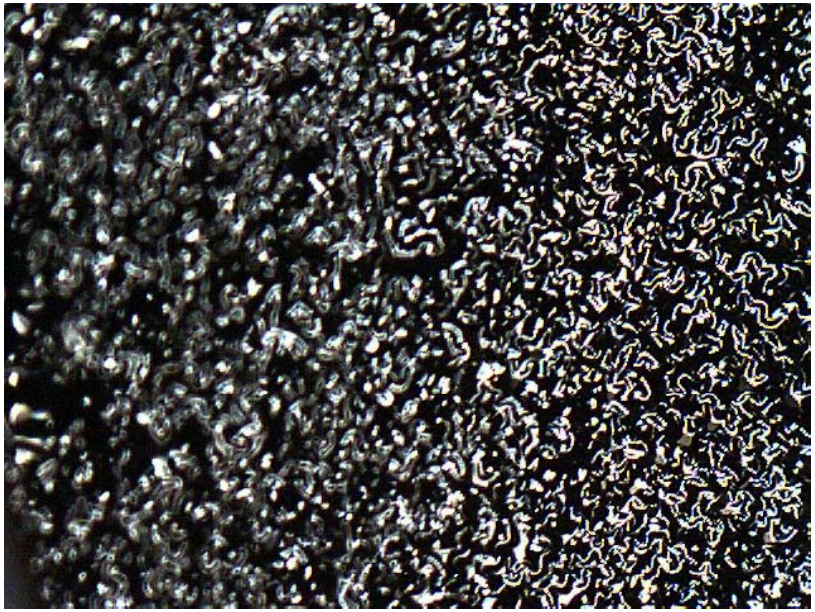
$C_2 + e = C_2^{0^*} + e + h\nu$ ▪▪▪ Swan Band

Mass spectrometry of colliding double plumes of C



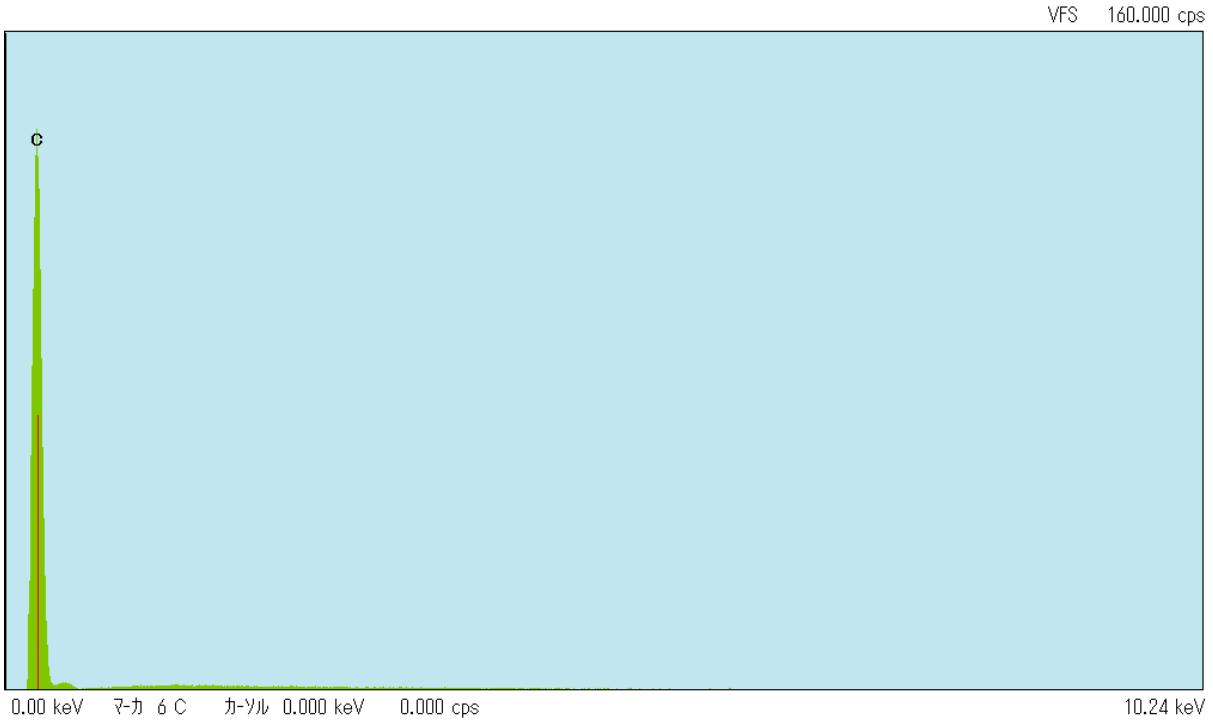
Carbon deposits from LEAF-CAP



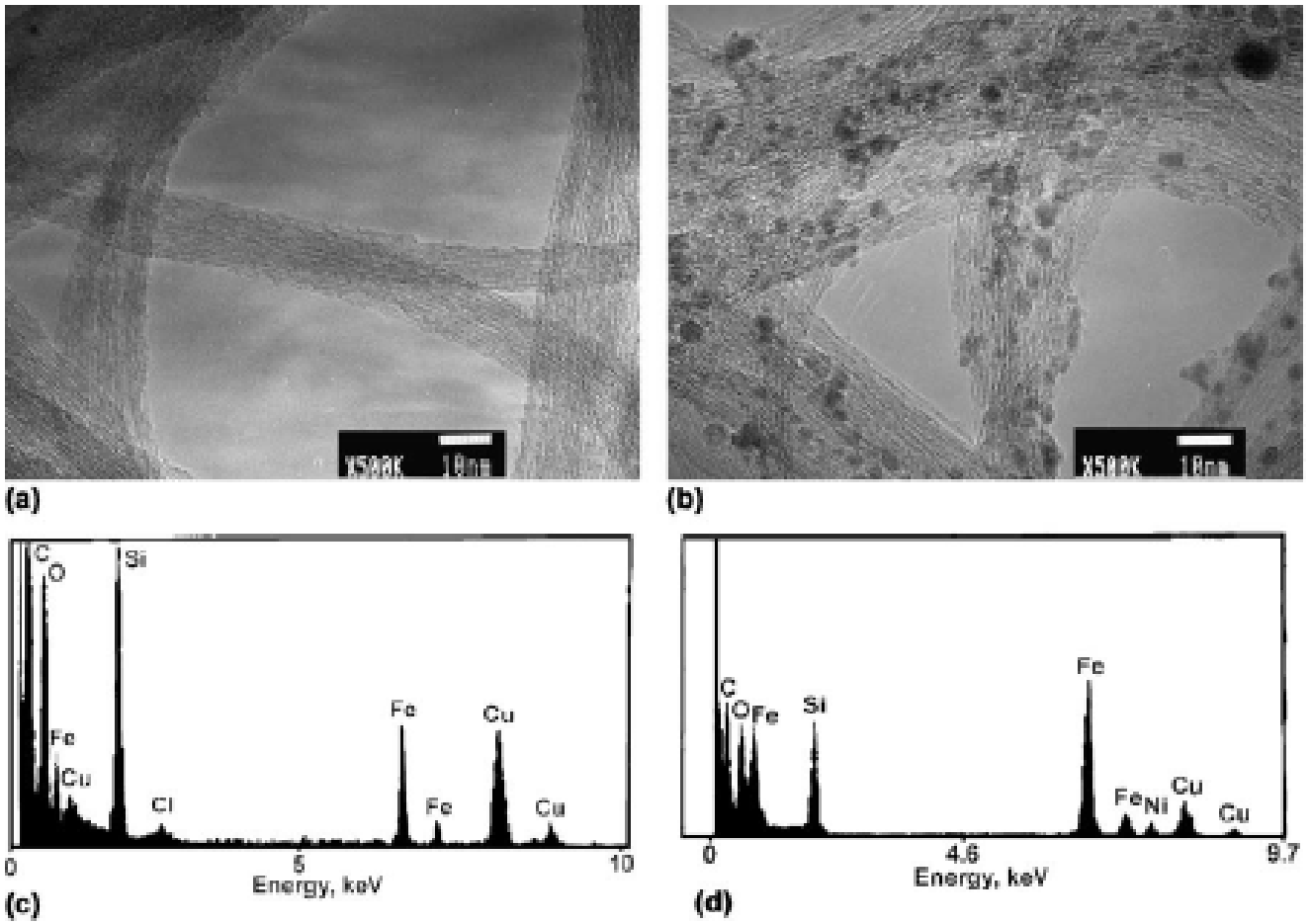


Carbon nano-materials (CNT etc.) from LEAF-CAP

EPMA analysis of C-nano materials from LEAF-CAP



CNT literature data



Proposed modeling for the US-Japan collaboration

- Particle emission behavior due to laser ablation and plume plasma properties to be modeled by **the HIEGHTS code**

- Aerosol formation behavior and A&M reaction dynamics to be analyzed by **an ab-initio MD code(?)**

Summary and future plans

- Data from LEAF-CAP exps. Indicte:
  - Colliding Cu and Al plumes seem to recombine
    - No particular radiation observed
  - Colliding C plumes leads to cluster formation
    - C2 band radiation and line radiation due to association
    - CNT-like structures formed in deposits
  - Magnetic deflection effects demonstrated
    - Real-time deposition rate measurements
- Future plans include:
  - Colliding Li (LiPb alloys) and W plume experiments
  - More plume diagnostics
  - Variable magnetic cusp field