SL_COMB

Laboratori Nazionali di Frascati
Resp. Naz.: Dr. Massimo Ferrario

Lecce
Milano
Napoli
Roma I
Roma II

COMB= Coherent (resonant) plasma Oscillations by Multiple electron Bunches

Scientific Interest

Plasma-based accelerators are of great interest because of their ability to:

•Sustain ultra-high accelerator gradients (~10 GV/m) enabling the development of compact accelerators.

•Produce extremely short electron bunches, enabling the production of advanced radiation sources

FACILITY SPARC_LAB
LABORATORI NAZIONALI DI FRASCATI

METHOD

HIGH ACCELERATOR GRADIENTS REQUIRE HIGH PEAK POWER

- Laser-driven plasma-based Wakefield Accelerator (LWFA)
- Particle-driven plasma-based Wakefield Accelerator (PWFA)

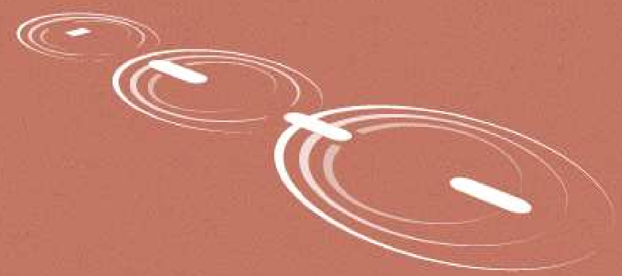
LWFA

In LWFA, the ponderomotive force of a laser pulse, traveling through an under-dense plasma, can excite a plasma wave with longitudinal electric fields larger than 10 GV/m. Electrons can then be accelerated up to ultra-relativistic energies on a centimeter scale. Terawatt-class lasers are needed in order to provide the required electric field.

Resonant PWFA

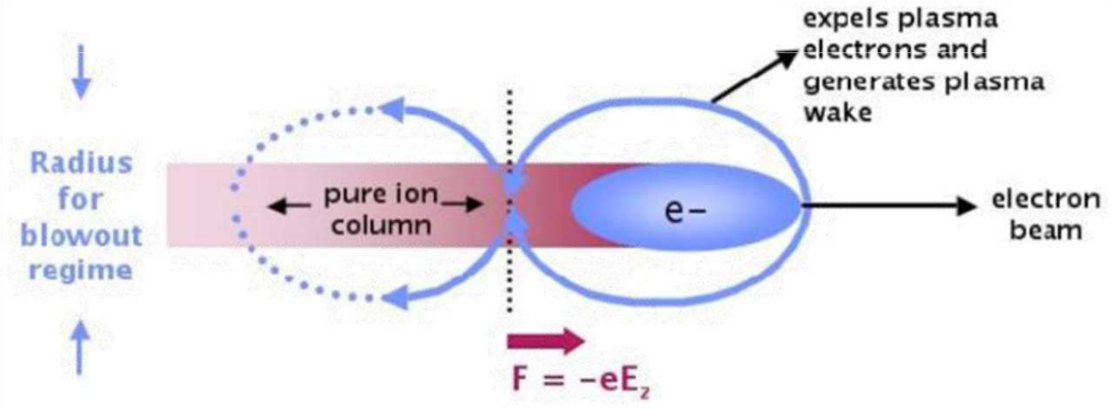
In PWFA the plasma wave is excited by the space charge forces of the driving electron bunch that displace the plasma electrons.

In that way the driving electron pulse can transfer a large fraction of its kinetic energy to a subsequent bunch (witness bunch) placed at a proper distance.

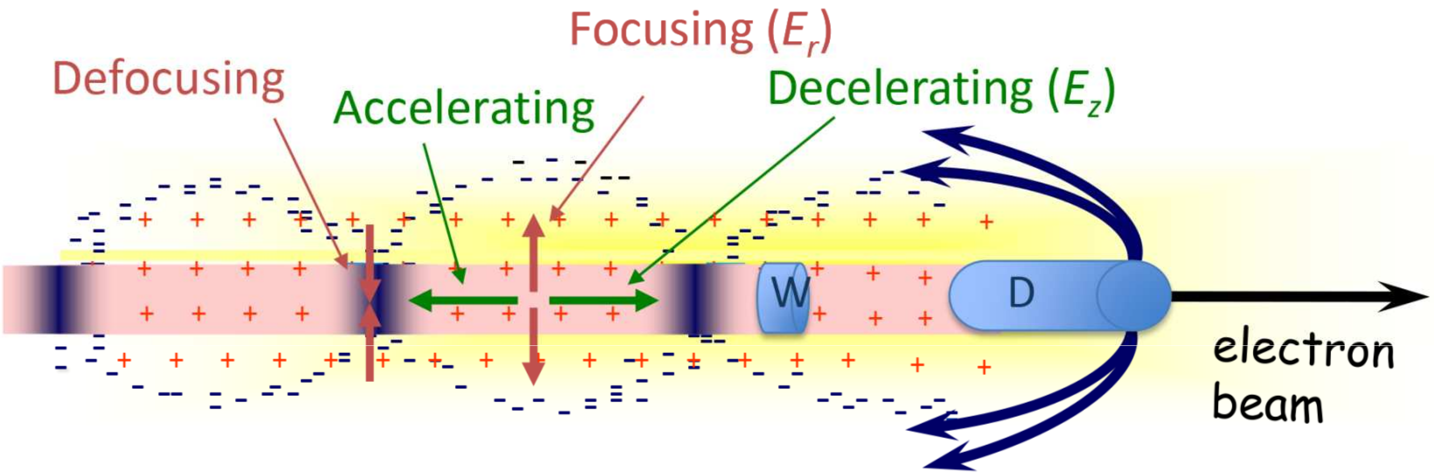


Particle-driven plasma-based Wakefield Accelerator (PWFA)

The high-gradient wakefield is driven by an intense, high-energy charged particle beam as it passes through the plasma.
The space-charge of the electron bunch blows out the plasma electrons which rush back in and overshoot setting up a plasma oscillation.



2-bunch Train PWFA



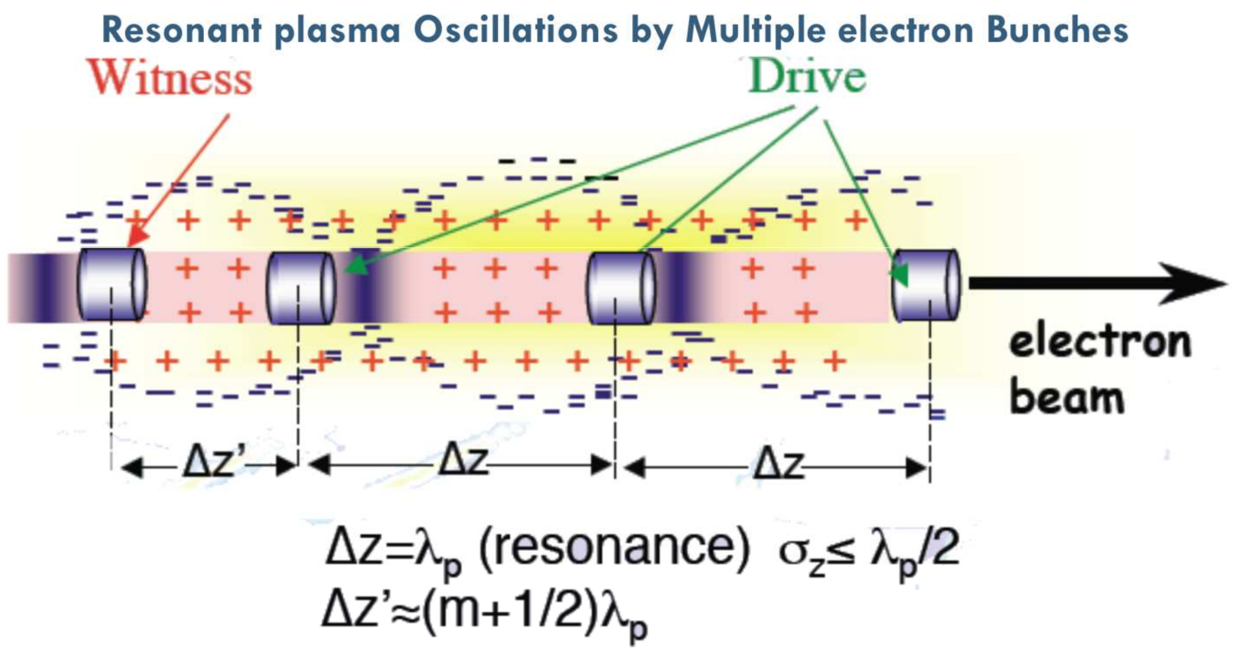
A second, appropriately phased accelerating beam (**witness beam**), containing fewer particles than the **drive beam**, is then accelerated by the wake.

Bunch train (D+W) for bunch acceleration

($\Delta E/E \ll 1$)

Particle-driven plasma-based Wakefield Accelerator (PWFA)

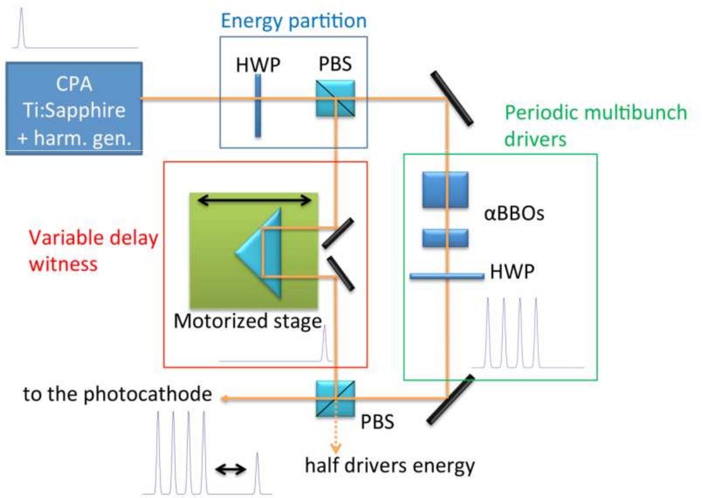
COMB Principle



❖ **Weak blowout regime** with resonant amplification of plasma wave by a train of high brightness electron bunches produced by **Laser Comb** technique ➔ **5 GV/m** with a train of 3 bunches, 100 pC/bunch, 50 μm long, 20 μm spot size, in a plasma of density 10^{22} e^-/m^3 at λ_p=300 μm ?

Experimental activities

Laser system for Driving and Witness bunches generation ready!



R&D activity on photocathodes preparation and test for the minimazation of thermal emittance, still preserving quantum efficiency, temporal response and robustness

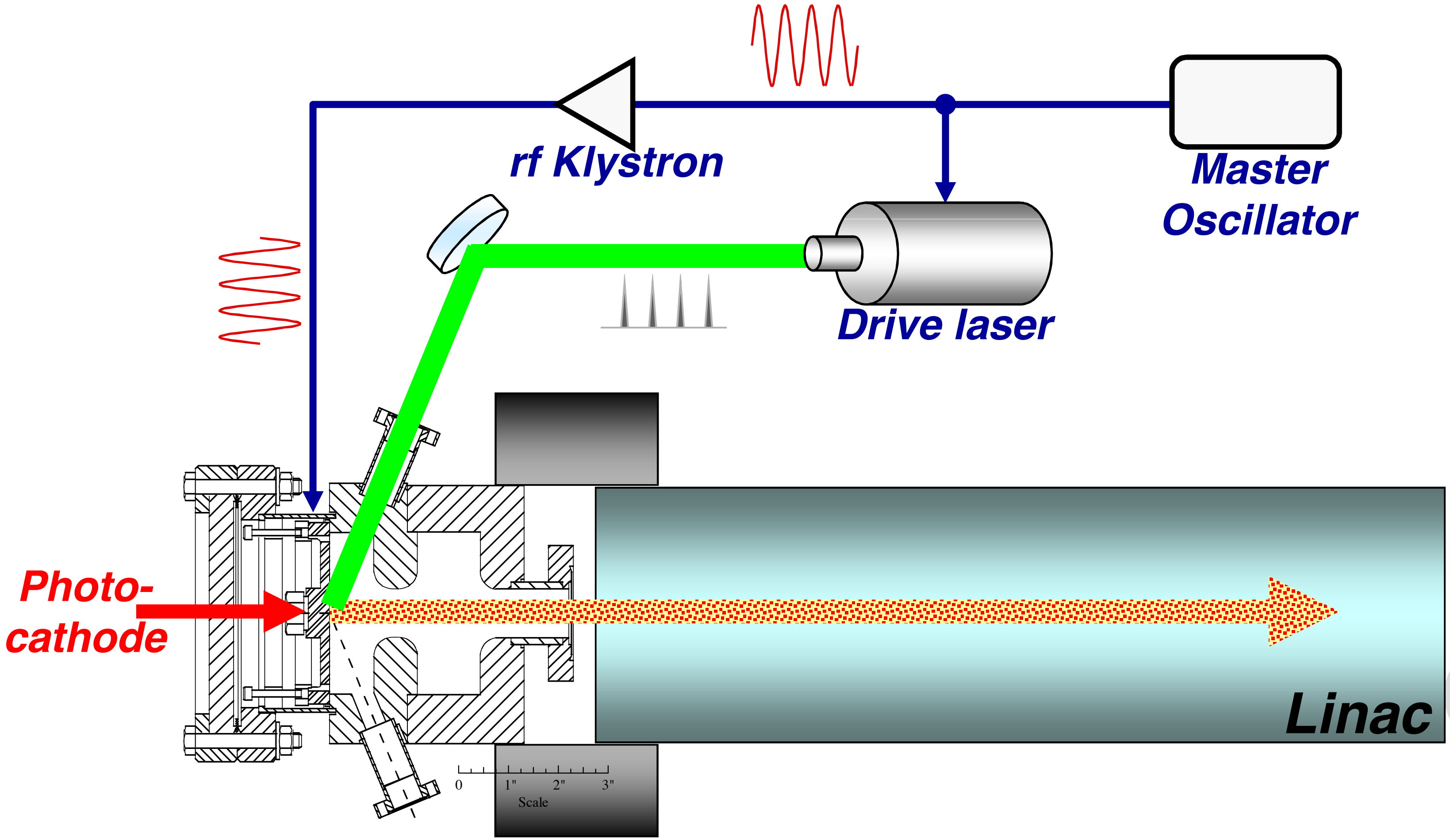
Attività di ricerca a Lecce

R&D of photocathodes with
higher performances

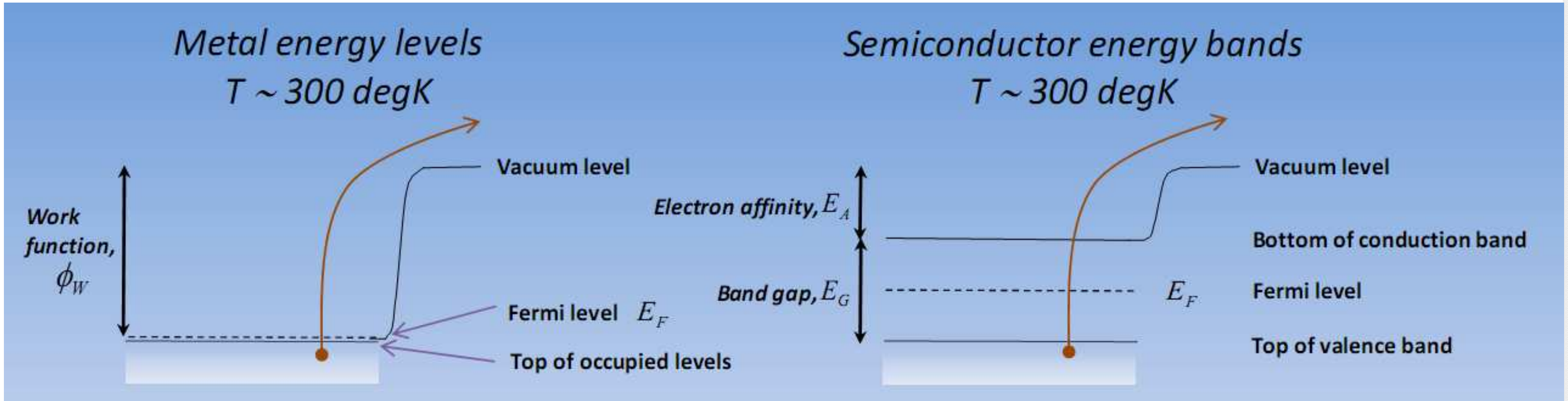
PHOTOINJECTORS & PHOTOCATHODES

High Power FEL Demands on Photocathode:

CHARGE PER BUNCH:	0.1 - 1 nC in 10-50 ps pulse
FIELD:	10 - 100 MV/m in pressure of 10-8 Torr (approx)
OPERATION:	Robust, Prompt, Operate At Longest λ
LIFETIME:	Longevity & Reliability Paramount



PHOTOCATHODES



Metals

- Low thermal emittance;
- Fast response time;
- Better tolerance to vacuum contaminations.

Low QE

Semiconductors

- High QE,
- Low dark current

- Long response time,
- High thermal emittance,
- Very sensitive to the vacuum contaminations.

DESIRED PHOTOCATHODE PROPERTIES

➢Quantum efficiency
- High QE at the longest possible wavelength;
- Fast response time : <100 ps;
- Uniform emission;
- Easy to fabricate;
- Low dark current.

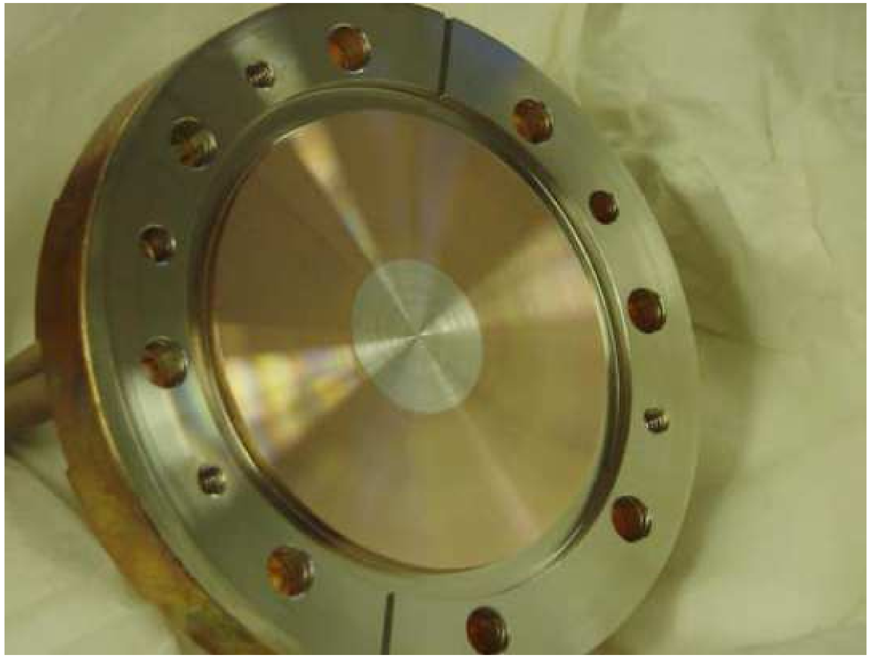
➢Intrinsic emittance $\varepsilon_{\text{intrinsic}} \propto \sqrt{\hbar\omega - \phi_{eff}}$
- As low as possible;
- Smooth surface (few nm) to minimize emittance grown due to surface roughness;
- Tunable, controllable with photon wavelength and with the work function.

➢Lifetime, robustness, survivability
- Require long operating lifetime > 1 year;
- Easy, reliable cathode cleaning or rejuvenation.

WHICH METAL?

Metallic photocathodes	***Φ_W (eV)***	***λ(nm), $\hbar w$ (eV)***	***QE***	***REFERENCES***
Cu	4.5	266, 4.66 193, 6.42	$1.4\text{x}10^{-4}$ $1.5\text{x}10^{-3}$	**T. Srinivasan-Rao et al., JAP, 1991** **E. Chevallay et al., NIMA, 1994**
Mg	3.7	266, 4.66	$1.8\text{X}10^{-3}$ $1.3\text{X}10^{-3}$	**L. Cultrera et al., NIMA, 2008;** **H. J. Qian et al. APL, 2010**
Y	3.0	266, 4.66 406, 3.01	$3.3\text{X}10^{-4}$ $1.1\text{X}10^{-5}$	**L. Cultrera et al., J. Nanosci. Nanotech.,2009;** **A. Lorusso et al., NIMB (in press)**
Pb	4.0	250, 4.96 193, 6.42	$6.9\text{x}10^{-4}$ $1.5\text{x}10^{-3}$	**D. Dowell et al., NIMA, 2010;** **J. Smedley et al., Phys.Rev. ST Accel. Beams, 2008**

Mg-BASED PHOTOCATHODES



- ✓ **Mg CATHODE PREPARED BY FRICTIONAL WELDING TECHNIQUE** *(Wang et al. Proc. of LINAC 2002);*

- ✓ **Mg CATHODE MADE BY PRESS FITTING TECHNIQUE** (*Srinivasan-Rao et al. JAP 1995; Wang et al. NIM A, 1995; Qian et al. APL, 2010*);

- ✓ **Mg CATHODE PREPARED BY HOT ISOSTATIC PRESSING TECHNIQUE** (*Nakajyo et al. Jpn.J. Appl. Phys., 2003).*

Weak points:

- The joint between Mg and Cu is a source of RF breakdown;
- Partial oxidation of the Mg during the pre-heating;
- Cross contamination during polishing procedure.

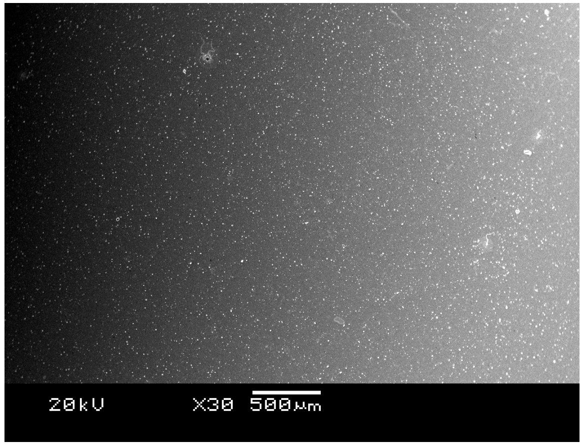
WHY PULSED LASER ABLATION DEPOSITION TECHNIQUE FOR PRODUCING METALLIC PHOTOCATHODES?

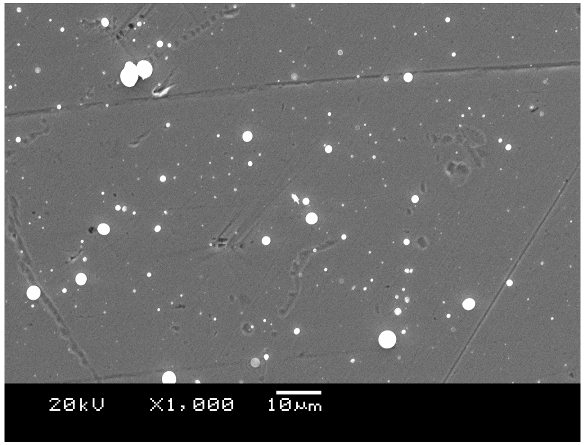
- FILMS HIGHLY ADHERENT TO THE SUBSTRATE;
- HIGH QUALITY FILMS;
- VERSATILE TECHNIQUE.

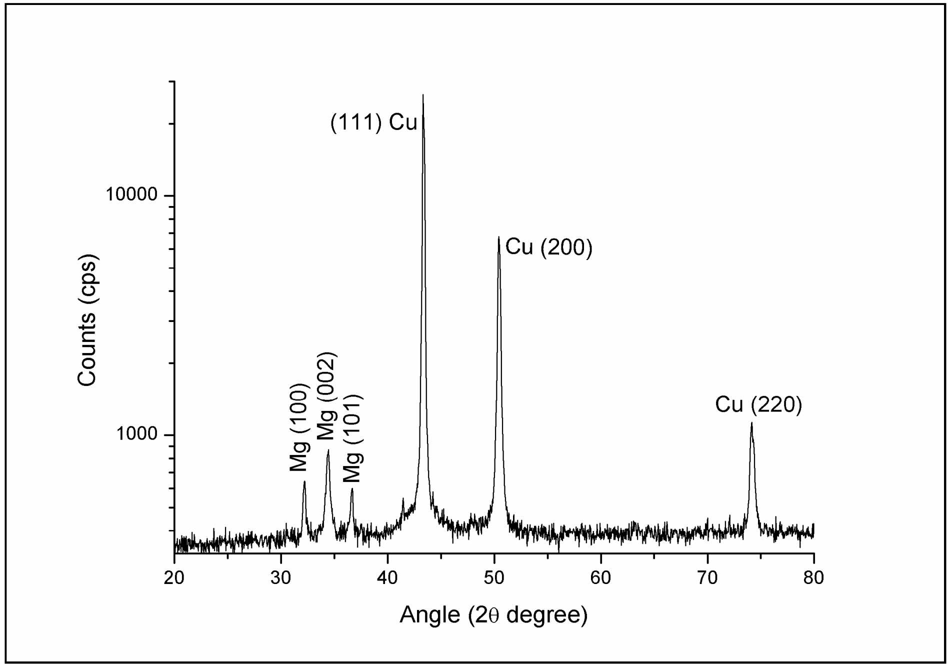
Weak points:

- Inhomogenity of the deposited thin films due to the narrow angular distribution of the plasma plume and to the plume deflection effect;
- Presence of particulates and droplets on the film surface.

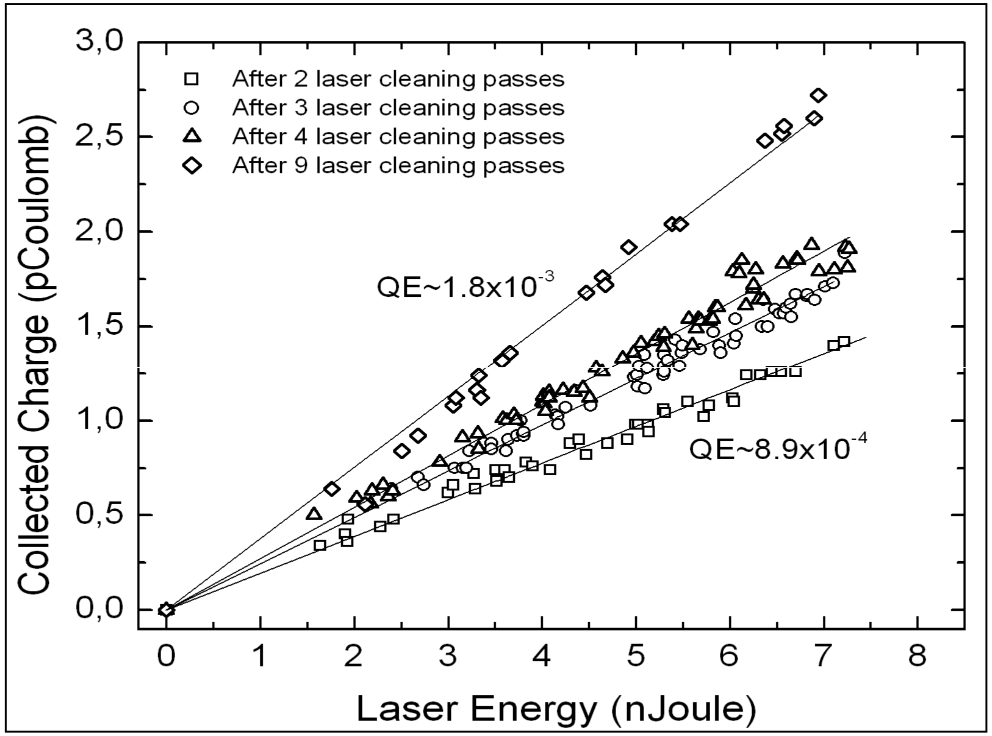
Mg THIN FILM ON Cu SUBSTRATE





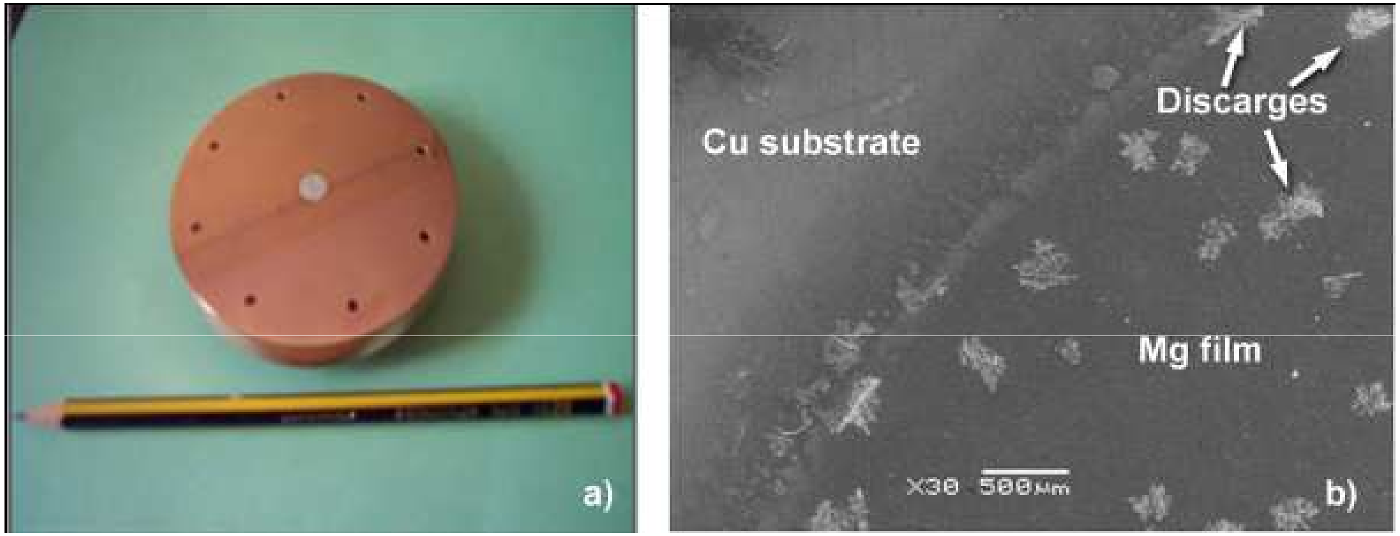


PHOTOCATHODES BASED ON *Mg* THIN FILM (*LASER Nd:YAG @ 266 nm*)



After the laser cleaning, single-photon induces photoemission

MAIN RESULTS OBTAINED WITH Mg-BASED PHOTOCATHODES IN THE RF-GUN OF **UCLA** (UNIVERSITY OF CALIFORNIA, LOS ANGELES)

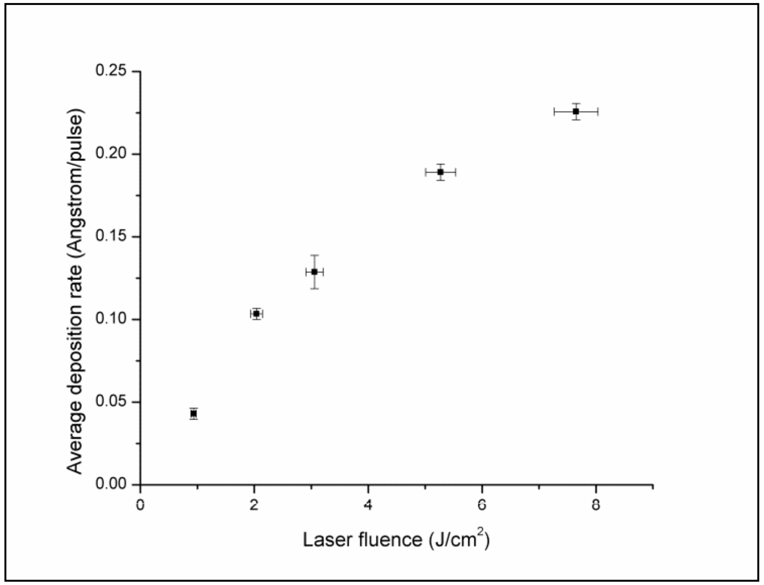


- no film delamination;
- low dark current (some μA) at 110 MV/m;
- EDX maps showed that Mg film had not been removed from Cu back-flange.

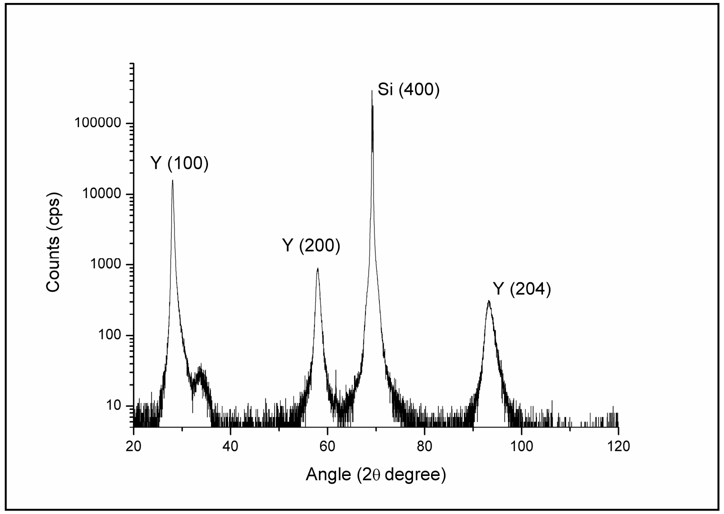
IS YTTRIUM MORE INTERESTING AND SUITED THAN MAGNESIUM?

- 2° HARMONIC (400 nm~3.1 eV) OF Ti:Sa LASER INSTEAD OF 3° HARMONIC (266 nm~4.66 eV) CAN BE USED;
- IT MEANS MORE AVAILABLE AND STABLE ENERGY OF THE PHOTOCATHODE DRIVE LASER;
- REDUCED THERMAL EMITTANCE ($\varepsilon_{\text{intrinsic}} \propto \sqrt{\hbar\omega - \phi_{eff}}$)

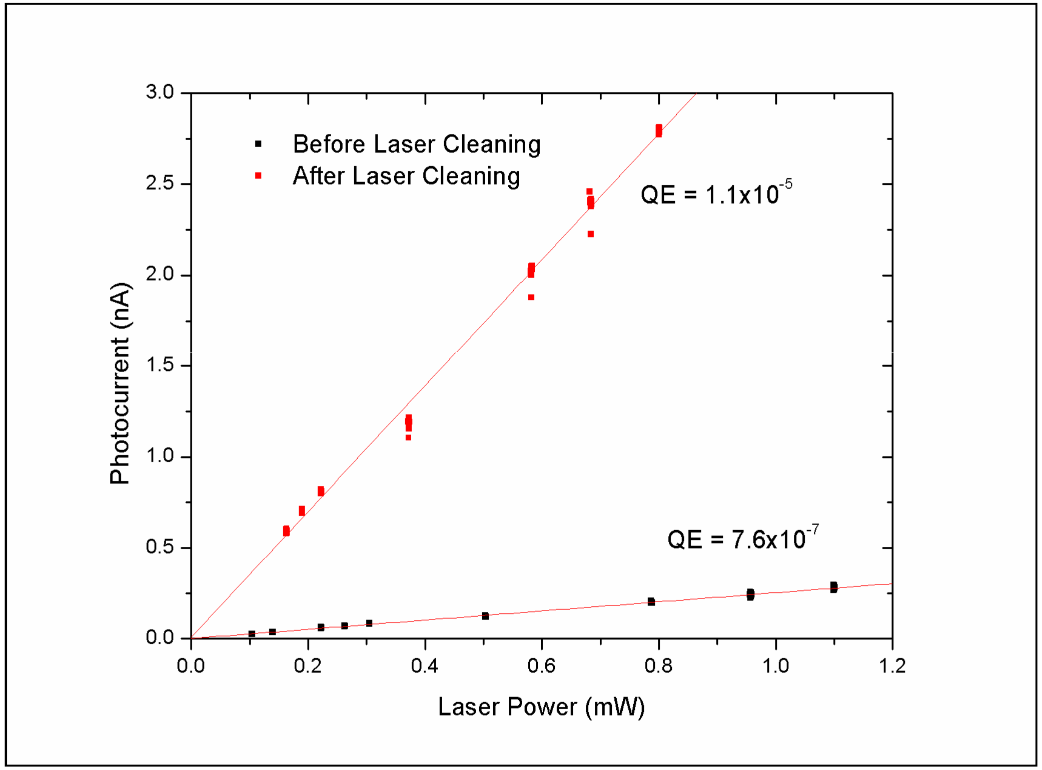
Y FILM CHARACTERIZATION



Y thickness =*650nm* as measured by profilometer and by SEM cross section

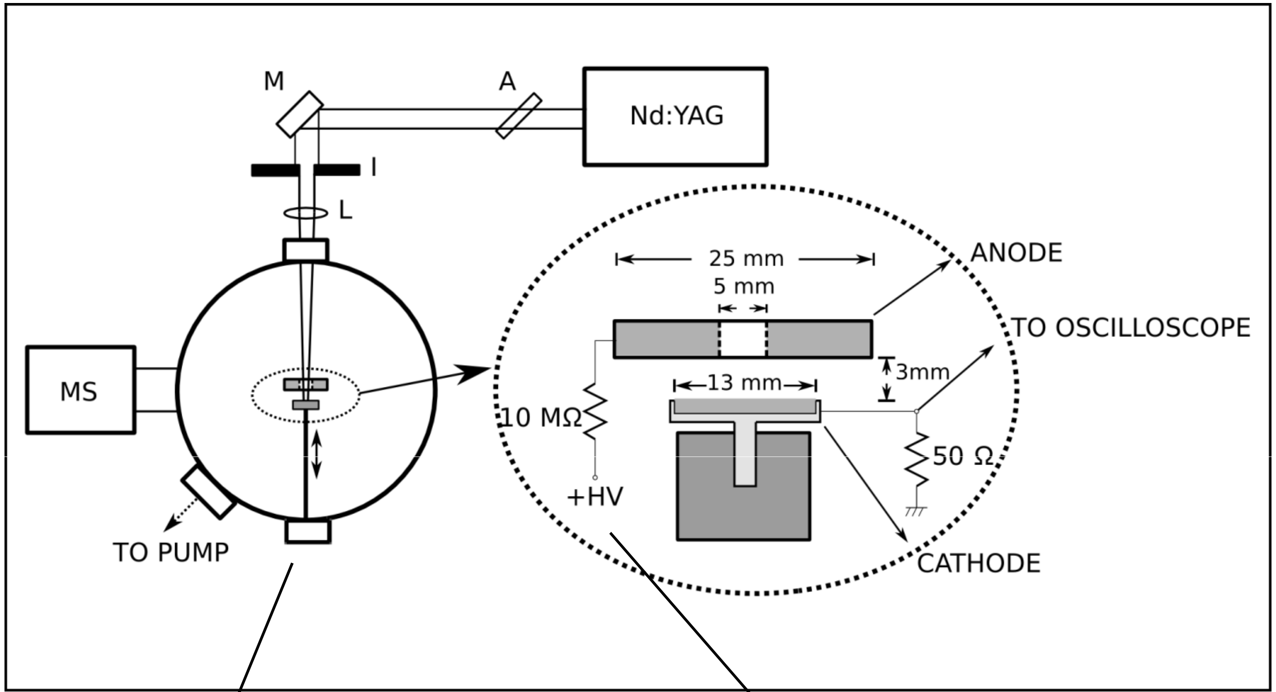


PHOTOCATHODES BASED ON *Y* THIN FILM (*LASER DIODE @ 406 nm*)



LASER CLEANING PROCESSES ARE MANDATORY TO IMPROVE THE QE OF PHOTOCATHODES.

PHOTODIODE CELL FOR TESTING THE QUANTUM EFFICIENCY OF PHOTOCATHODES



Richieste finanziarie

Vacuometro per alto vuoto (10^{-10} mbar)

Alimentatore DC 15kV/1mA

Anagrafica
SL_COMB-Lecce 2015

Nome	**Qualifica**	**%**
De Giorgi Maria Luisa	Ricercatore Universitario	30
Di Giulio Massimo	Professore Associato	20
Gontad Francisco	Assegnista	50
Lorusso Antonella	Ricercatore Universitario	40
Perrone Alessio	Professore Ordinario	60
Solombrino Luigi	Professore Associato	50

Richieste Finanziarie SL_COMB-Lecce 2015

Missioni	2 k€
Materiale di consumo	2 k€
Strumentazione	15 k€