*Seminar*

Institutul de Fizică Atomică

# PULSE and IMPULSE of ELI

*(Extreme Light Infrastructure)*

## IV. Electron Pulse Coupling with Dielectric Targets by Cruise Effect for High-Intensity External Field Controlled Lasing

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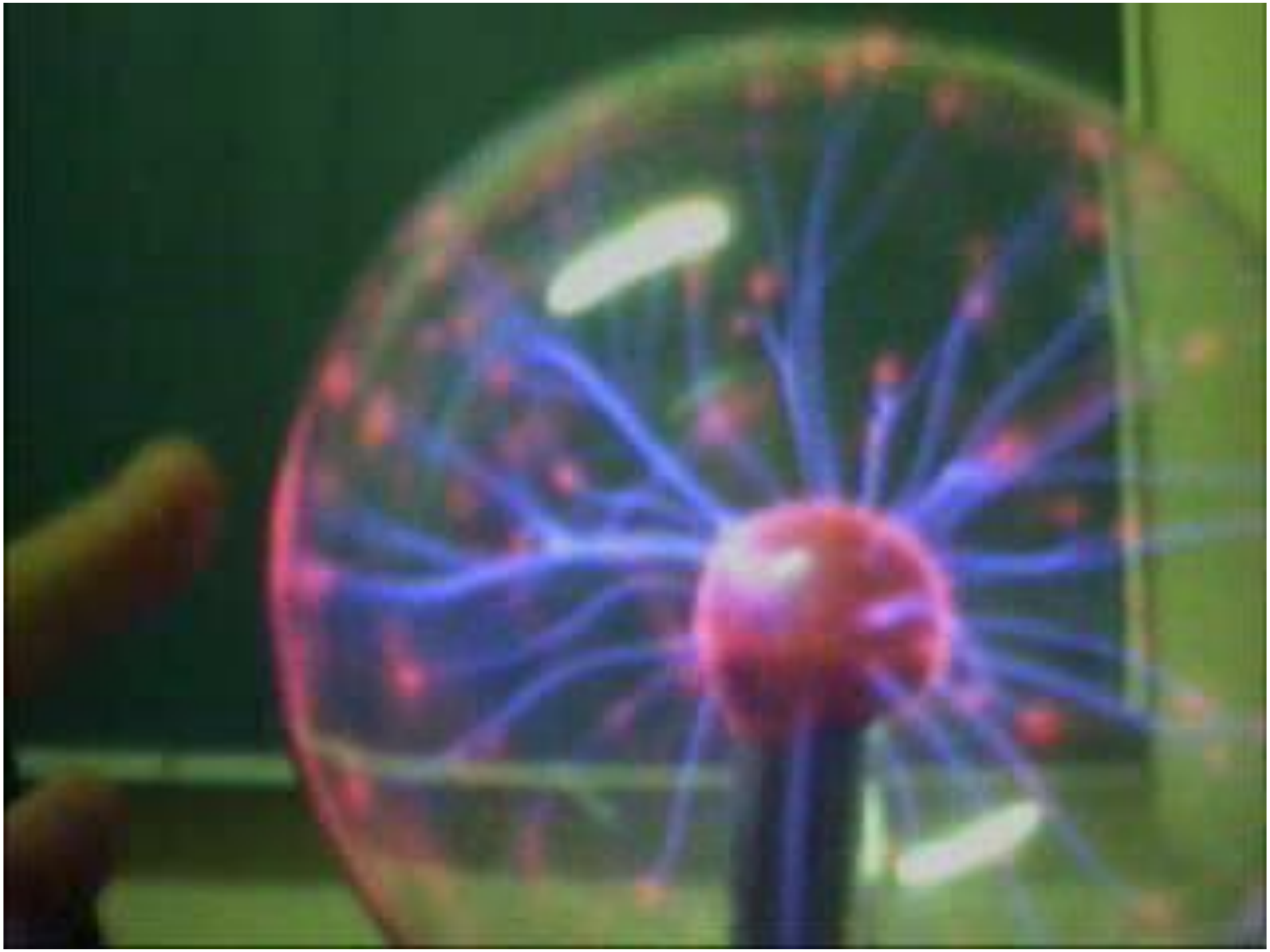
New arguments are presented in favor of the polaritonic model for the transport of the electrons, synchronously with a plasma assisted high-power laser pulse. This kind of transport is in agreement with electron beam acceleration by bubble model, and an experimental validation is proposed. Moreover, this transport could improve the coupling with different targets, and particularly with a fiber target. A short review will be done of the electron transport on the dielectric fiber surface by the Cruise Effect and the extension of this effect to laser accelerated electron beams is analyzed. For very thin fiber the coupling between cruising electrons and the fiber material are performed mainly by virtual photons and the geometrical characteristic could be of interest for gamma ray laser studies (http://handle.dtic.mil/100.2/ADA398179), for channeling studies and also for a new kind of directional hard X ray sources.

**Joi 8.07.2010, ora $10^{00}$, Sala de Consiliu, Bloc Turn, etaj 9**



In memoriam of Professor Geavit Musa

INSTITUTE of ATOMIC PHYSICS
Magurele-Bucharest

# PULSE and IMPULSE of ELI
# ("Extreme Light Infrastructure")

# VI. ELECTRON PULSE COUPLING WITH DIELECTRIC TARGETS by CRUISE EFFECT for HIGH-INTENSITY EXTERNAL FIELD CONTROLLED LASING

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# PULSE and IMPULSE of ELI (Extreme Light Infrastructure)

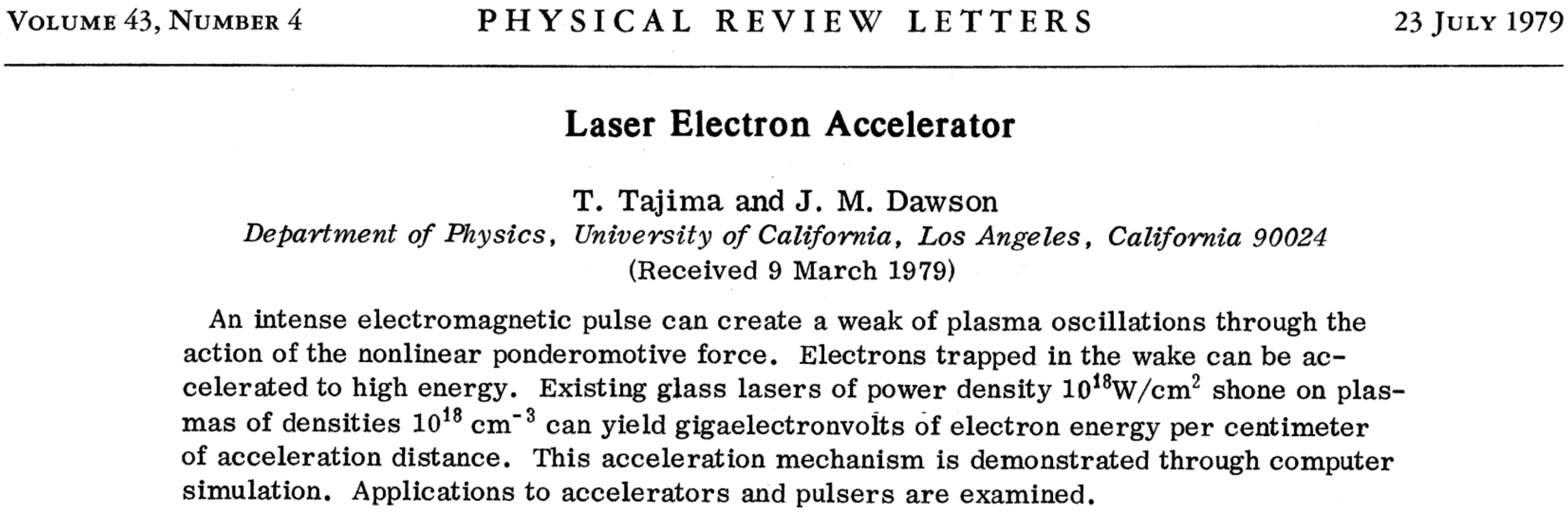
- I. ELECTRON PULSES ACCELERATED by POLARITONIC LASER BEAMS
- Marian APOSTOL, Institute of Physics and Nuclear Engineering, Magurele-Bucharest

- II. EXPERIMENTAL ASPECTS of ELECTRON PULSES ACCELERATED by HIGH - INTENSITY POLARITONIC LASER BEAMS
- Mihai GANCIU, Institute of Lasers, Plasma and Radiation Physics, Low Temperature Plasma Laboratory, Magurele – Bucharest

- III. GAMMA LASER CONTROLLED by HIGH-INTENSITY EXTERNAL FIELDS
- Marian APOSTOL, Institute of Physics and Nuclear Engineering, Magurele-Bucharest

- IV. ELECTRON PULSE COUPLING WITH DIELECTRIC TARGETS by CRUISE EFFECT FOR HIGH-INTENSITY EXTERNAL FIELD CONTROLLED LASING
- Mihai GANCIU, Institute of Lasers, Plasma and Radiation Physics, Low Temperature Plasma Laboratory, Magurele – Bucharest

- http://www.ifa-mg.ro/seminarii.php



VOLUME 43, NUMBER 4 PHYSICAL REVIEW LETTERS 23 JULY 1979

# Laser Electron Accelerator

T. Tajima and J. M. Dawson
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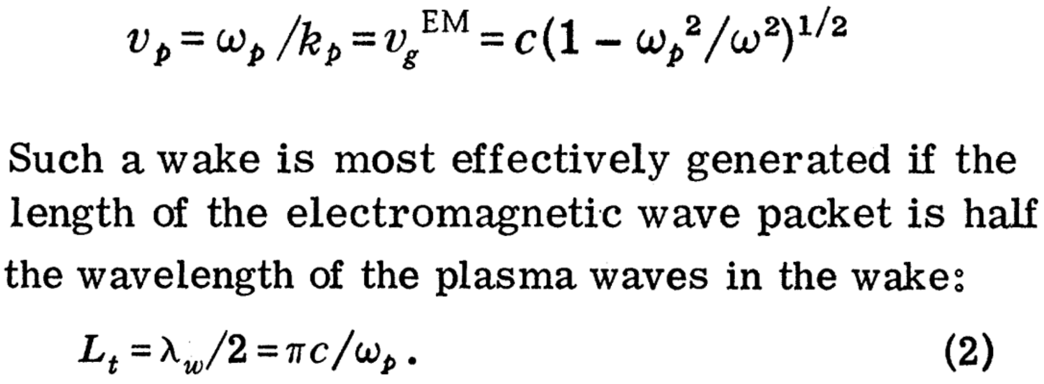
(Received 9 March 1979)

An intense electromagnetic pulse can create a weak of plasma oscillations through the action of the nonlinear ponderomotive force. Electrons trapped in the wake can be accelerated to high energy. Existing glass lasers of power density $10^{18}$W/cm$^2$ shone on plasmas of densities $10^{18}$ cm$^{-3}$ can yield gigaelectronvolts of electron energy per centimeter of acceleration distance. This acceleration mechanism is demonstrated through computer simulation. Applications to accelerators and pulsers are examined.



$$v_p = \omega_p / k_p = v_g^{\mathrm{EM}} = c(1 - \omega_p^2/\omega^2)^{1/2}$$

Such a wake is most effectively generated if the length of the electromagnetic wave packet is half the wavelength of the plasma waves in the wake:

$$L_t = \lambda_w/2 = \pi c/\omega_p . \qquad (2)$$

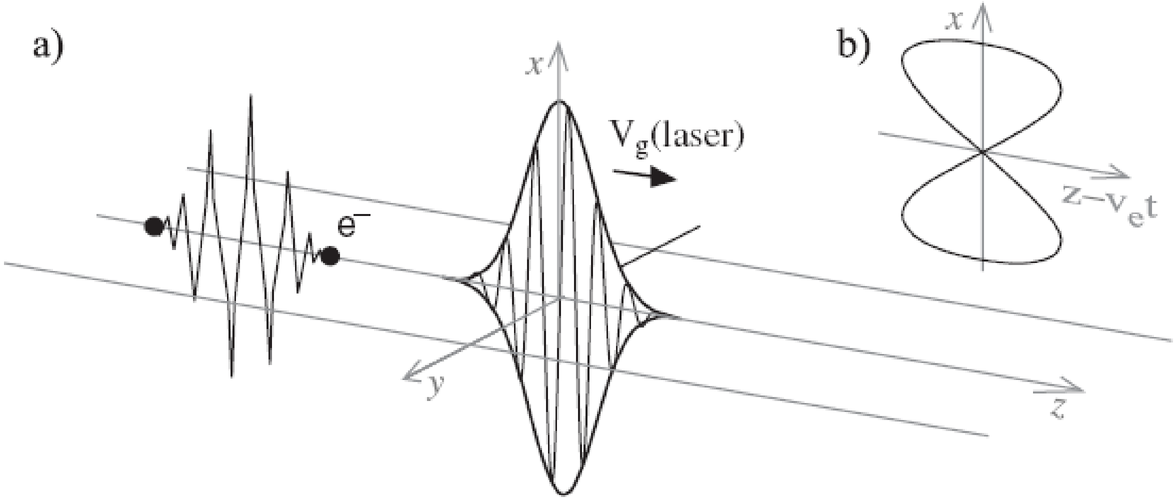


**Fig. 2.3.** (**a**) A relativistic laser pulse, propagating from *left* to *right* on the $z$-axis, has passed an electron. Its electric field points along the $\hat{x}$-direction, the magnetic field (not shown) into $\hat{y}$. The electron has moved along a zig-zag–shaped trajectory in the $\hat{x}$–$\hat{z}$-plane and stopped at rest after the passage. (**b**) “Figure of 8” electron trajectory in a frame moving with the mean forward velocity of the electron (averaged rest frame of the electron)

$$\boldsymbol{F}_{\mathrm{L}} = \frac{d\boldsymbol{p}}{dt} = -\mathrm{e} \cdot \left(\boldsymbol{E} + \boldsymbol{v} \times \boldsymbol{B}\right).$$

$$p_x = -\frac{\mathrm{e}E_0}{\omega m_0 c}\,\sin(\omega t - kz) = -a_0\,\sin(\omega t - kz),$$

relativistic parameter $a_0 = \mathrm{e}E_0/\omega m_0 c$.

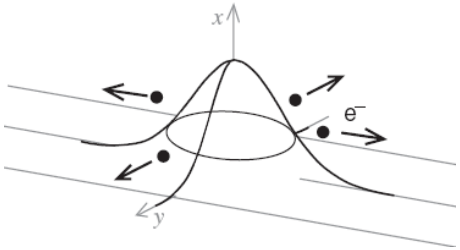
$$p_z = \left(\frac{\mathrm{e}E_0}{\omega m_0 c}\right)^2 \sin^2(\omega t - kz) = \frac{a_0^2}{2}\,\sin^2(\omega t - kz)\,.$$

H. Schwoerer et al., *Lasers and Nuclei*,
Lect. Notes Phys. 694 (Springer, Berlin Heidelberg 2006), DOI 10.1007/b11559214

The energy of the electron is can also be expressed with help of $a_0$:

$$E = \gamma m_0 c^2 = \left(1 + \frac{a_0^2 \sin^2(\omega t - kz)}{2}\right) \cdot m_0 c^2 \,.$$

Now we eventually have to come up with real numbers of electron energies versus electric field and light intensity: From (2.7) follows that the kinetic energy of the electron reaches its rest energy at $a_0 = \sqrt{2}$. For a laser wavelength of $\lambda = 800\,\mathrm{nm}$, this corresponds to an electric field strength of $E_0 \approx 5 \cdot 10^{12}\,\mathrm{V/m}$ and a light intensity of $I \approx 4 \cdot 10^{18}\,\mathrm{W/cm^2}$, following from $I = \frac{1}{2} c \epsilon_0 E_0^2$. At the currently almost maximum intensity of $10^{20}\,\mathrm{W/cm^2}$ the electric field is $E_0 \approx 3 \cdot 10^{11}\,\mathrm{V/cm}$ and the mean kinetic energy of the electron amounts to 6 MeV. This relativistic electron energy gave rise to the term relativistic optics. Nevertheless, because of the planeness and transverse infinity of the light wave, our electron is again at rest after the pulse has passed it. It was moved forward, but no irreversable energy transfer took place.



$$F_{\mathrm{pond}} = -\frac{\mathrm{e}^2}{2 m_0 \omega^2} \cdot \nabla (E)^2 \,.$$

An irreversable acceleration of an electron in a light field can be achieved only by breaking the transverse symmetry of the light field. This is obtained in real propagating light fields or laser beams, which all exhibit a transverse spatial intensity profile

H. Schwoerer et al., *Lasers and Nuclei*,
Lect. Notes Phys. 694 (Springer, Berlin Heidelberg 2006), DOI 10.1007/b11559214

# Experimental set up

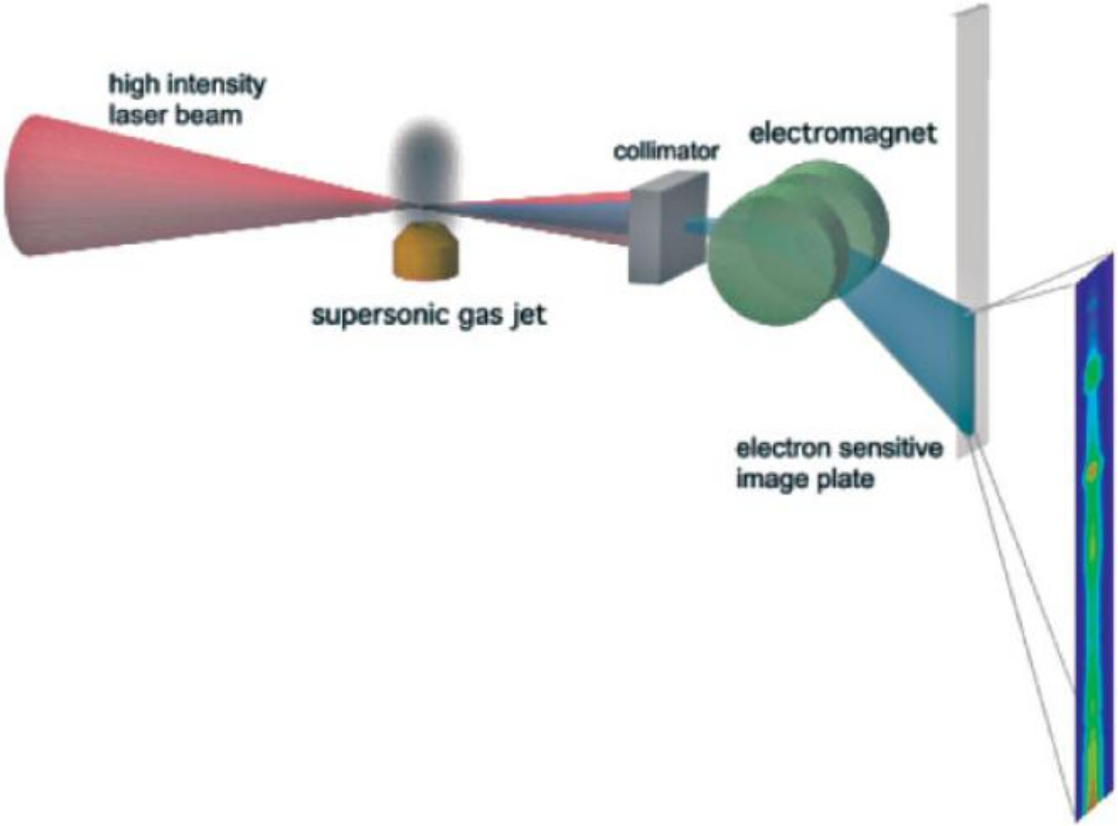


**Figure 3** (online color at: www.lpr-journal.org) Experimental set up for laser wakefield acceleration experiments. The high intensity laser beam is focused onto the front edge of a low density helium gas jet target. The electron generated travel along with the laser pulse as it exits the target and they are subsequently dispersed using a magnetic spectrometer to determine the energy spectrum.

K. Krushelnick and V. Malka Laser & Photon. Rev. **4**, No. 1, 42–52 (2010) / **DOI** 10.1002/lpor.200810062

# Acceleration in the "bubble" regime

The breakthrough experiments in 2004 [16–18] showed electron acceleration over a range of electron densities (which is controlled by varying the target gas pressure). With the plasma density below a "threshold" value no energetic electrons were observed, however as the density was increased, very high energy electrons suddenly could be produced with the most energetic electrons reaching greater than 100 MeV in energy and having an output beam divergence of less than 1 degree. However the most interesting aspect of the energy spectra from these first experiments was that, in this regime, the electron energies were "quasi-monoenergetic" and, indeed, generally consisted of a single narrow spike – which could have an energy bandwidth of less than 5% (Fig. 4). As mentioned previously this is in contrast to the energy spectra of all previous laser acceleration experiments in which essentially 100% energy spreads were observed. As the density was increased, the peak energy of the observed electrons was observed to decrease and the spectra begin to assume the broad "Maxwellian" shape which was characteristic of previous experiments and which the number of energetic electrons drops off rapidly towards higher energy (Fig. 5).

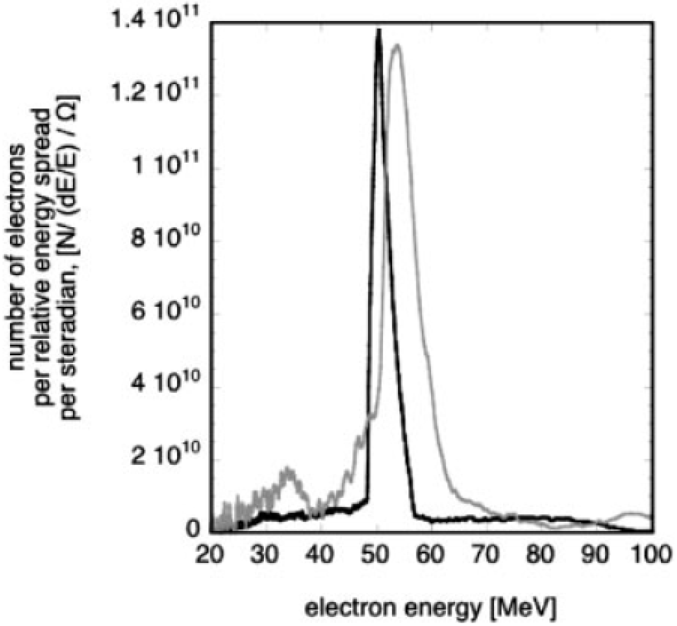


**Figure 4** Two measured electron spectra with $E = 500\,\mathrm{mJ}$ laser at a density of $2 \times 10^{19}\,\mathrm{cm}^{-3}$. Shots are taken from the same shot series. The spectra show the relatively narrow energy spread of the electron beams directly generated by the short pulse laser interaction. The spectra show data taken under similar experimental conditions showing the shot-to-shot variability of the electron beams produced.

K. Krushelnick and V. Malka Laser & Photon. Rev. **4**, No. 1, 42–52 (2010) / **DOI** 10.1002/lpor.200810062

# Electron Self-Injection and Trapping into an Evolving Plasma Bubble

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(Received 24 June 2009; published 25 September 2009)

The blowout (or bubble) regime of laser wakefield acceleration is promising for generating monochromatic high-energy electron beams out of low-density plasmas. It is shown analytically and by particle-in-cell simulations that self-injection of the background plasma electrons into the quasistatic plasma bubble can be caused by slow temporal expansion of the bubble. Sufficient criteria for the electron trapping and bubble's expansion rate are derived using a semianalytic nonstationary Hamiltonian theory. It is further shown that the combination of bubble's expansion and contraction results in monoenergetic electron beams.

The resulting plasma bubble follows in the wake of the laser pulse propagating with the group velocity $v_0/c \approx 1 - 1/2\gamma_0^2$ ($\gamma_0 \approx \omega_0/\omega_p$), where $\omega_p = \sqrt{4\pi e^2 n_0/m}$ is the electron plasma frequency and $\omega_0 \gg \omega_p$ is the laser frequency. Strong longitudinal ($E_x$) and transverse electric fields inside the bubble are responsible for acceleration and focusing of the relativistic electrons which can, under the right circumstances, be injected into the bubble from the ambient plasma. The latter process of injection and trapping is the focus of this Letter. Although several analytic and semiempirical models of the plasma bubble have recently been put forward [9,10], the complex process of trapping ambient plasma electrons into the bubble is not well understood. Understanding electron trapping or injection from the background plasma has important practical implications because the alternatives (such as, for example, using a second laser pulse [11–13]) are technically demanding. Moreover, injection into a nonevolving bubble in the most interesting case of $\gamma_0 \gg 1$ (corresponding to tenuous plasmas) that could potentially result in single-stage multi-GeV acceleration [14] requires a very large bubble size [9].

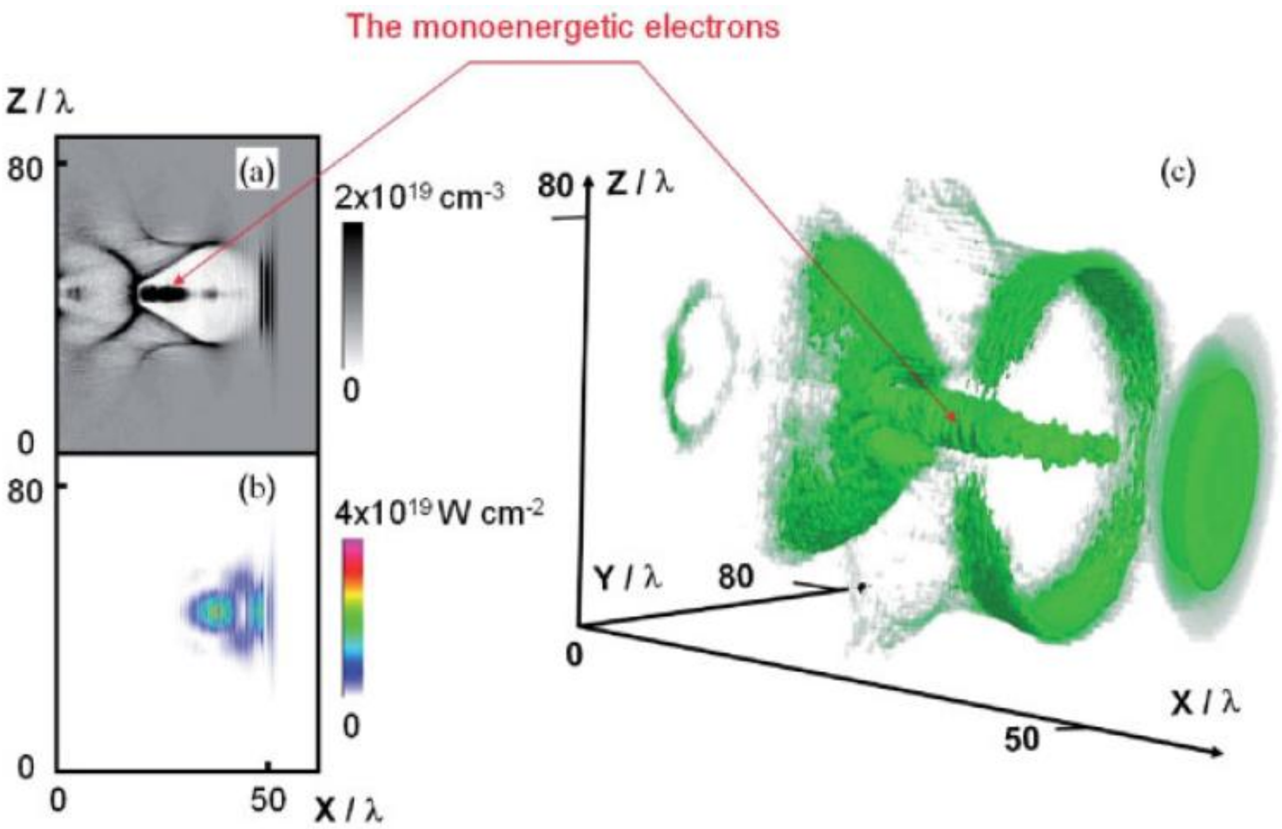


**Figure 6** (online color at: www.lpr-journal.org) 3D PIC simulation results for the case $n_e = 6 \times 10^{18}\,\mathrm{cm}^{-3}$. Frames (a) and (b) show distributions of electron density and laser intensity in the XZ-plane which is perpendicular to the polarization direction and passes through the laser axis. Frame (c) provides a 3D volume view on the electron density distribution in the bubble. The image shows an isosurface at $n_e = 2 \times 10^{19}\,\mathrm{cm}^{-3}$.

Recent theoretical work has developed scalings for acceleration in the bubble regime [24]. However the main questions which remain outstanding for the further development of such sources in this regime are typically those of experimental control of the acceleration process. How can the laser and plasma parameters be adjusted to enable control of the electron beam energy, charge, energy spread, divergence, emittance and pointing? These properties have all been observed to vary more than desired – and consequently the most significant results of the research reported recently involved insights into improving the stability of these critical beam parameters.

K. Krushelnick and V. Malka Laser & Photon. Rev. **4**, No. 1, 42–52 (2010) / **DOI** 10.1002/lpor.200810062

# Polaritonic pulse of laser accelerated electrons

**Assume** $\omega_p \ll \omega_0 = ck_0$; then, the group velocity

$$v \simeq c\left(1 - \frac{\omega_p^2}{2\omega_0^2}\right) \simeq c$$

**The First Great Equation**: Electron energy

$$E_{el} = \frac{mc^2}{\sqrt{1 - v^2/c^2}} \simeq \frac{\omega_0}{\omega_p} mc^2$$

**Second Great Equation** (electron flux)

$$\delta N = nd^2 \lambda_0 \frac{\varepsilon_p^2}{4mc^2 \varepsilon_0^2} \sqrt{\pi \varepsilon_{el} W_0}$$

$\varepsilon_p = \hbar\omega_p$, $\varepsilon_0 = \hbar\omega_0$ and $\varepsilon_{el} = e^2/d$,

# Polaritonic pulse of laser accelerated electrons

## Two Big Conclusions

Electron energy

$$E_{el} \sim \frac{\omega_0}{\omega_p} mc^2$$

Electron flux

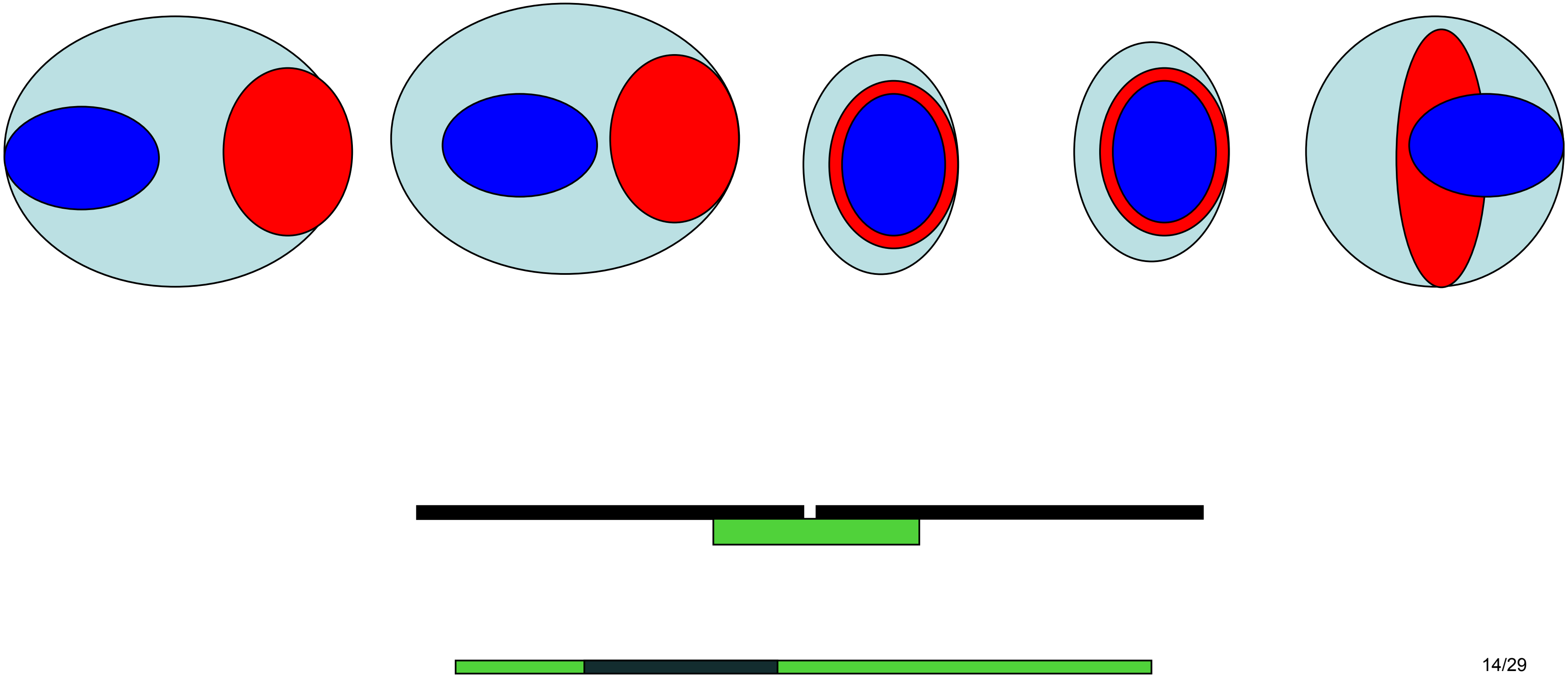
$$\delta N \sim n d^{3/2} \frac{\omega_p^2}{mc^2 \omega_0^2} \sqrt{I_0}$$

## Efficiency coefficient

$$\eta = \frac{W_{el}}{W_0} = n d^2 \lambda_0 \frac{\varepsilon_p}{4\varepsilon_0} \sqrt{\frac{\pi \varepsilon_{el}}{W_0}} \ll 1$$

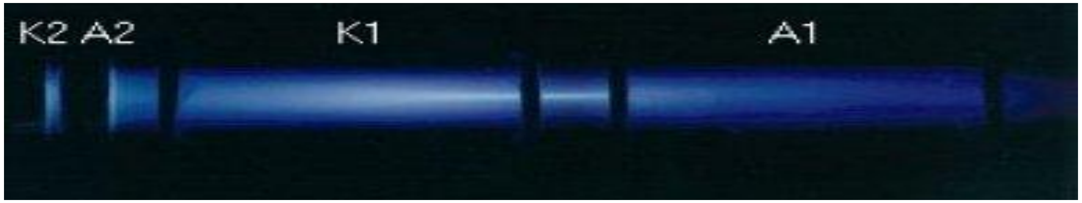
# Polaritonic pulse of laser accelerated electrons

- Experiment



Self-organization and polarization of a mixture of oil and zeolit granules subjected to a high intensity electric field induced by a Corona discharge

# Cruise Effect



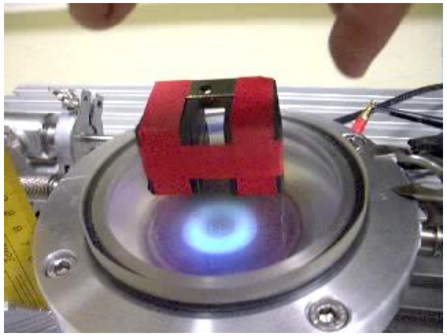
- Phenomenology:

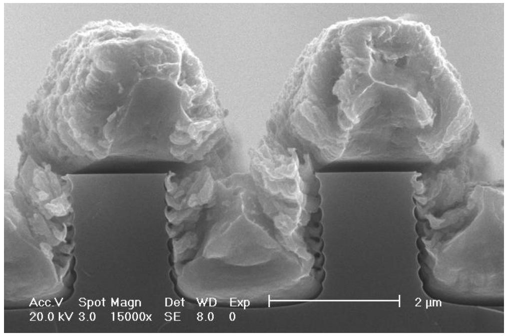
- in the case of dielectric fiber: positive charging of the dielectric fiber, due to efficient $e^-$ emission under $e^-$ and photons bombardment → *the beam is attracted*

- in the case of metallic wire: no possibility for return current → negative charging → *the beam is repelled*

M. Ganciu , E.Dewald, M. Nistor, D. Penache, I.I. Popescu, V. Zoran, “Surface guided electron beams on dielectric fibers (the cruise effect)” Rom. Journ. Phys. **39**, 787 (1994)

- Confinement and transport of electrons in a French Romanian cooperation 1
- Avoiding the fillamentation



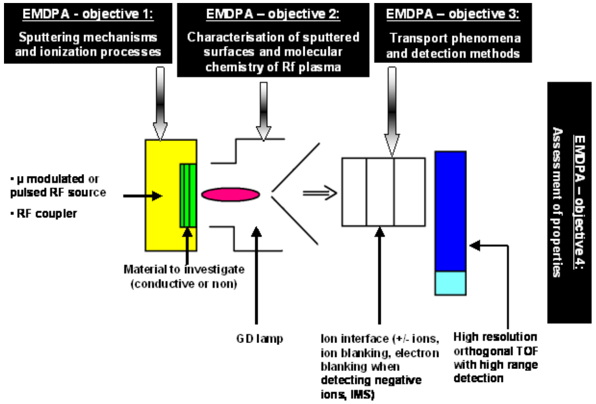


LPGP-Orsay
Materia Nova –Mons
IMN – Nantes
CEA – Grenoble
NILPRP - Bucarest

Mihai Ganciu-Petcu, Michel Hecq, Stephanos Konstantinidis, Jean-Pierre Dauchot, Jean Bretagne, Ludovic de Poucques, Michel Touzeau, „Deposition by magnetron cathodic pulverization in a pulsed mode with preionization”, European Patent Appl., 4447072.2, Mars 22, 2004, WO 2005/090632, http://www.fist.fr/fr/manufacture-devices/high-power-pulsed-magnetron-without-arc-formation-2.html

  - **Thin layer diagnostics by glow discharge optical and mass spectroscopy**

EMDPA – EU Project, Horiba Jobin Yvon, NILPRP



EMDPA - objective 1:
Sputtering mechanisms and ionization processes

EMDPA – objective 2:
Characterisation of sputtered surfaces and molecular chemistry of Rf plasma

EMDPA – objective 3:
Transport phenomena and detection methods

EMDPA – objective 4:
Assessment of properties

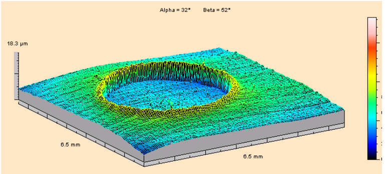
- µ modulated or pulsed RF source
- RF coupler

Material to investigate (conductive or non)

GD lamp

Ion interface (+/- ions, ion blanking, electron blanking when detecting negative ions, IMS)

High resolution orthogonal TOF with high range detection

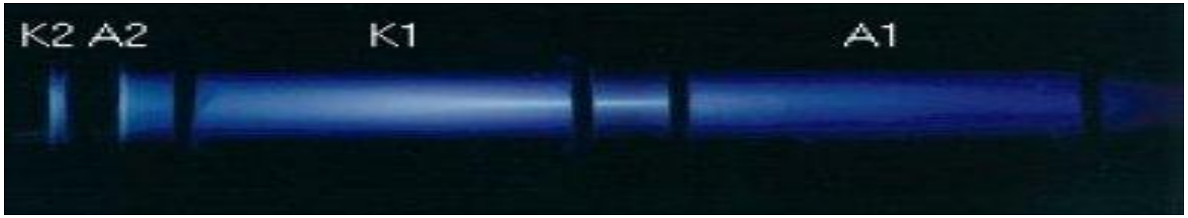


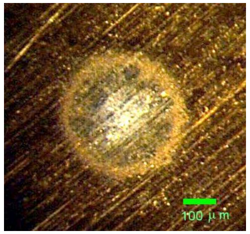
Mihai Ganciu, Constantin. Diplasu, Agavni Surmeian, Andreea Groza, Agnes Tempez, Patrick Chapon, Michel Casares, Olivier Rogerieux, "Source magnétron pour spectromètre à décharge luminescente", French Patent Application 0850055, 04 January 2008, PCT/FR2009/05008
http://www.bulletins-electroniques.com/actualites/59514.htm

- Confinement and transport of electrons in a French Romanian cooperation 2
- Using the fillamentation
- **Atmospheric pressure, nanosecond discharge, gas jet, runaway electrons**
  - LPGP, NILPRP, PlasmaBiotics

Mihai Ganciu, Anne Marie Pointu, Bernard Legendre, Johanes Orphal, Michel Vervloet, Michel Touzeau and Naget Yagoubi, “Method for decontamination using atomic nitrogen, US Patent Appl.10/610158, published December 30, 2004, WO 2005/002630, EP1638616 (A0), US Patent: 7229582 B2 / June 12, 2007 [http://www2.cnrs.fr/presse/journal/1971.htm](http://www2.cnrs.fr/presse/journal/1971.htm)

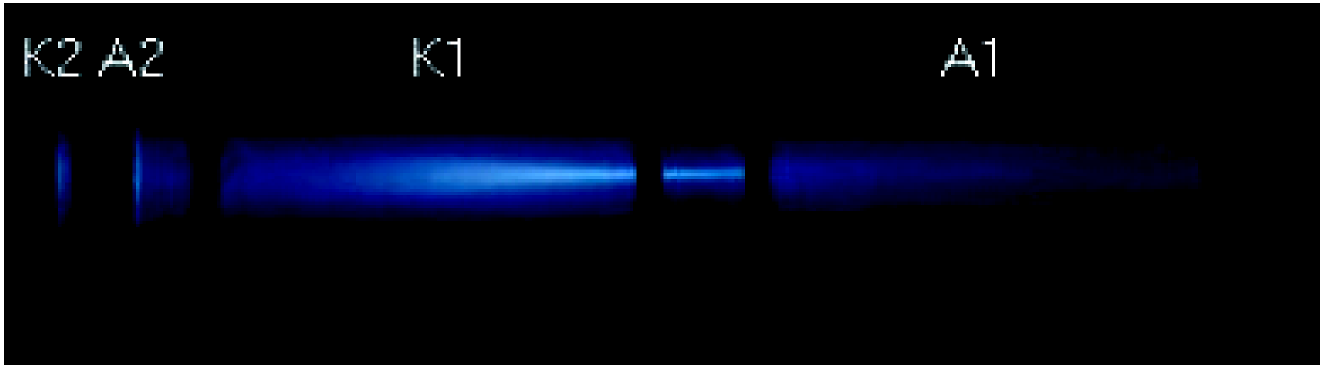
  - **Low pressure, nanosecond discharge, electron beams**
  - LPGP, NILPRP, EOARD





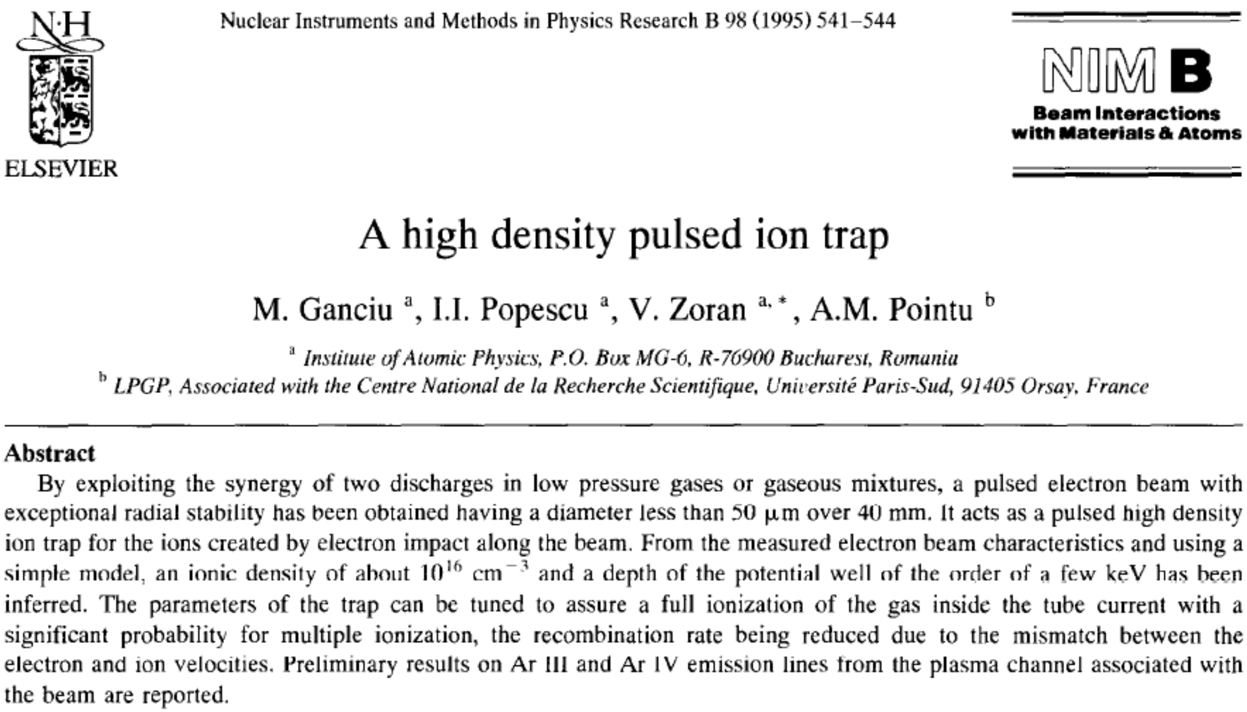
M.Ganciu, G.Modreanu, A.M.Pointu, I.I.Popescu, Generation of intense pulsed electron beams by superposition of two discharges J.Phys.D.-Appl .Phys. **27**, 1370 (1994)

# Pseudo-spark discharge with external electrodes



| | |
|---|---|
| Mean electron energy of the fast electrons from beam | 17.5 keV |
| FWHM of fast electron energy spectrum | 7 keV |
| Temporal width of the fast electron beam | 10 ns |
| Temporal width of the beam | 14 ns |
| Minimum beam diameter (from anodic target damage) | 50 m |
| Maximum beam current (~0.1 of maximum discharge current) | 65 A |

M.Ganciu, G.Modreanu, A.M.Pointu, I.I.Popescu, Generation of intense pulsed electron beams by superposition of two discharges J.Phys.D.-Appl .Phys. **27**, 1370 (1994)



ELSEVIER

Nuclear Instruments and Methods in Physics Research B 98 (1995) 541–544

NIM B
Beam Interactions with Materials & Atoms

# A high density pulsed ion trap

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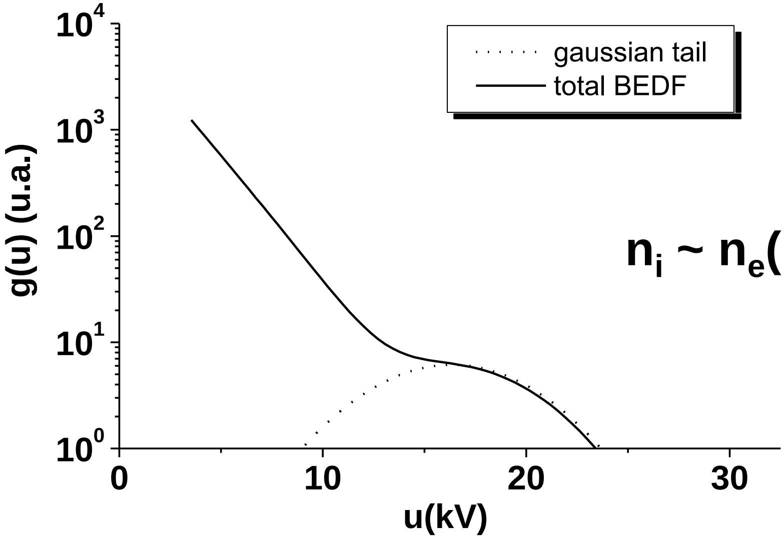
[b] *LPGP, Associated with the Centre National de la Recherche Scientifique, Université Paris-Sud, 91405 Orsay, France*

**Abstract**

By exploiting the synergy of two discharges in low pressure gases or gaseous mixtures, a pulsed electron beam with exceptional radial stability has been obtained having a diameter less than 50 μm over 40 mm. It acts as a pulsed high density ion trap for the ions created by electron impact along the beam. From the measured electron beam characteristics and using a simple model, an ionic density of about $10^{16}$ cm$^{-3}$ and a depth of the potential well of the order of a few keV has been inferred. The parameters of the trap can be tuned to assure a full ionization of the gas inside the tube current with a significant probability for multiple ionization, the recombination rate being reduced due to the mismatch between the electron and ion velocities. Preliminary results on Ar III and Ar IV emission lines from the plasma channel associated with the beam are reported.



$$n_i \sim n_e(1-v^2/c^2)$$

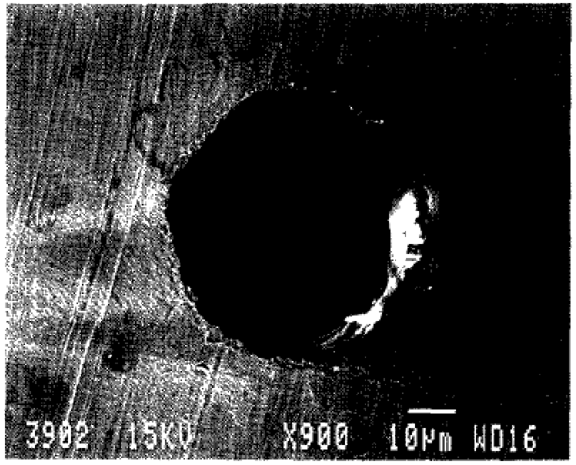
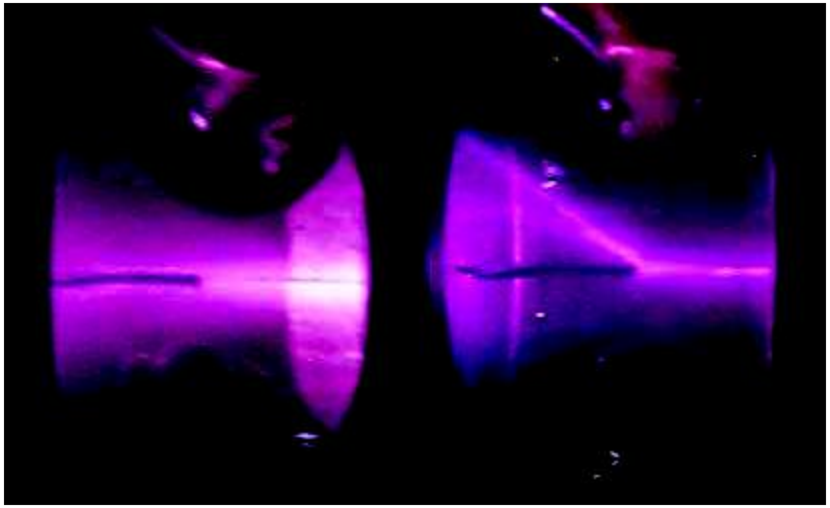
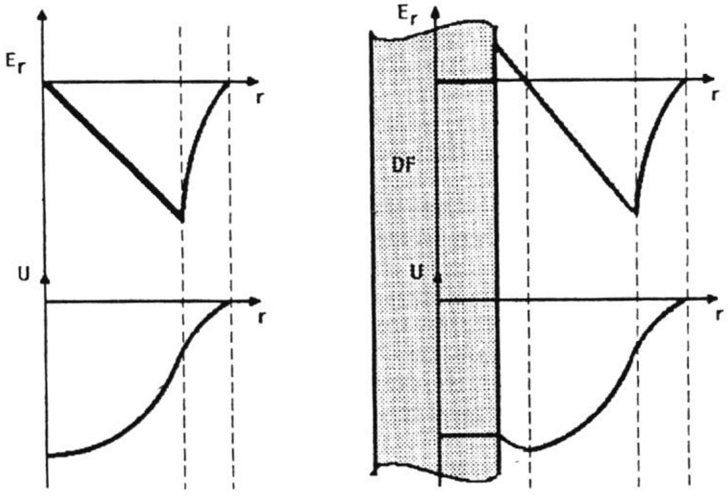


Fig. 3. Hole drilled by the electron beam in a 50 μm thick copper target.

A demonstrative portable device (20 × 12 × 4cm) allows to apply high voltage in trapezoidal pulses with 6 kV peak-to-peak amplitude on a sealed discharge tube. Two cylindrical electrodes, capacitively coupled with the internal dielectric surface of the discharge tube, ensure the coupling of 25 kHz electrical pulses with internal gas (argon at 0.3 Torr). The discharge tube is quite similar with a channel spark with dielectric electrodes. The filamentary plasma is associated with an electron beam and the fluorescence spot is induced by the impact of the magnetically deflected electron beam on the glass discharge tube wall.

M. Ganciu and A.M.Pointu, International Conference on Phenomena in Ionized Gases, Warsaw, 11-16 July 1999





a

b

*crude model:* static + monoenergetic

a. free cathode- anode space

b. with an axial dielectric fiber

X-ray emission associated has an intensity comparable to that generated by the electron beam totally stopped in a stainless steel anode.

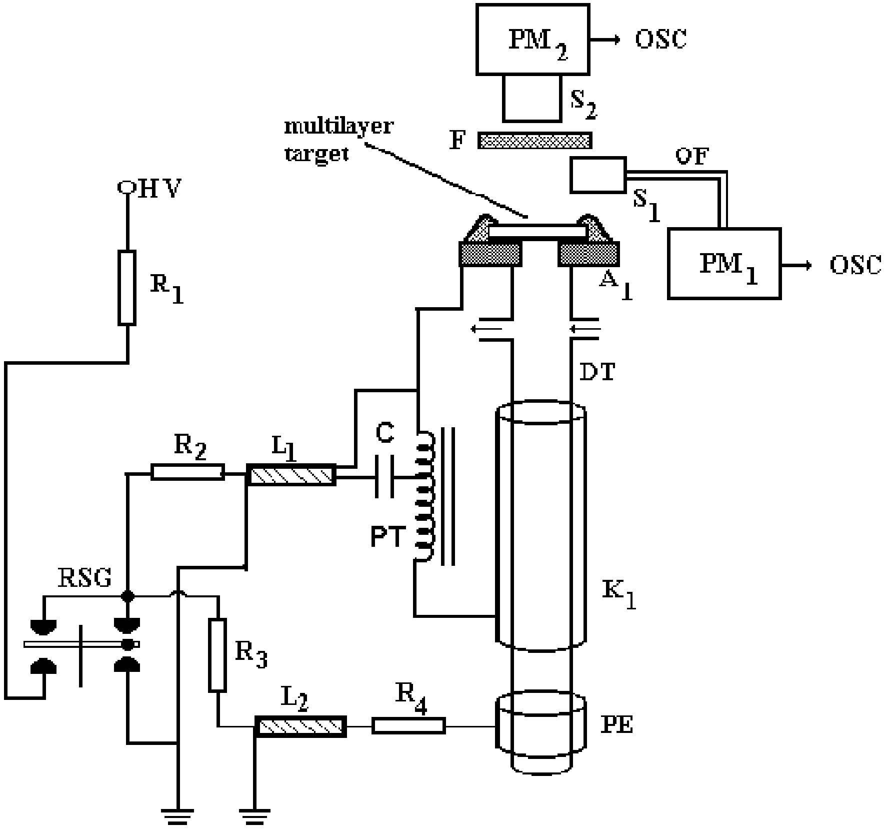
We anticipated that for a dielectric fiber as target, provided a proper plasma (laser or discharge plasma) is generated on the cruising surface the CE would work also for relativistic electrons. In this case the X-ray emission by bremstralung is main concentrated along the dielectric fiber inside a cone with an opening angle of $2/\gamma$ (where $\gamma$ is the relativistic factor for the fast electrons in the beam).

Under certain conditions, a dielectric fiber containing nuclear isomers such 178Hf m2 may become active medium for gamma ray emission. An X ray generator based on the scheme proposed in this paper may provide an optimum coupling of the radiation to the active medium. More specifically, assuming that the nuclear isomers are concentrated along the center of the fiber and the X rays are generated around the fiber, the radiation power density at the isomers is inversely proportional to the radius of the (cylindrical) emitting surface. This hopefully would pave the way towards fillamentary hard X-ray pumping sources strongly coupled with the irradiated active media, as requested for induced gamma emission. Accordingly, for the future our research will be devoted to investigate the CE on multilayer dielectric targets at higher electron beam densities and energies.

**contract F61708-96-WO193 with EOARD-US Air Force "Spatial and energetic characterisation of x-ray emission from inverse capillary discharges"**
http://handle.dtic.mil/100.2/ADA337641

**contract F61775-00-WE061 with EOARD-US Air Force "Fast pulsed X-ray sources tightly coupled with small targets for isomer triggering studies"**
http://handle.dtic.mil/100.2/ADA398179

# Experimental setup



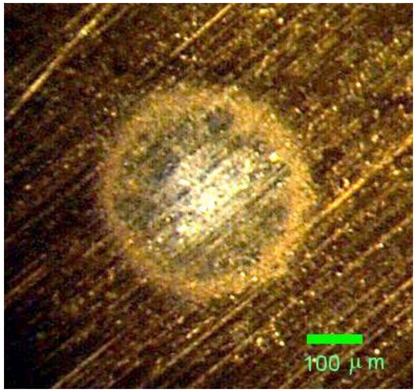


Photo of the multilayer target after the interaction with a monopulse electron beam when the melting threshold and the ablation threshold of gold were exceeded

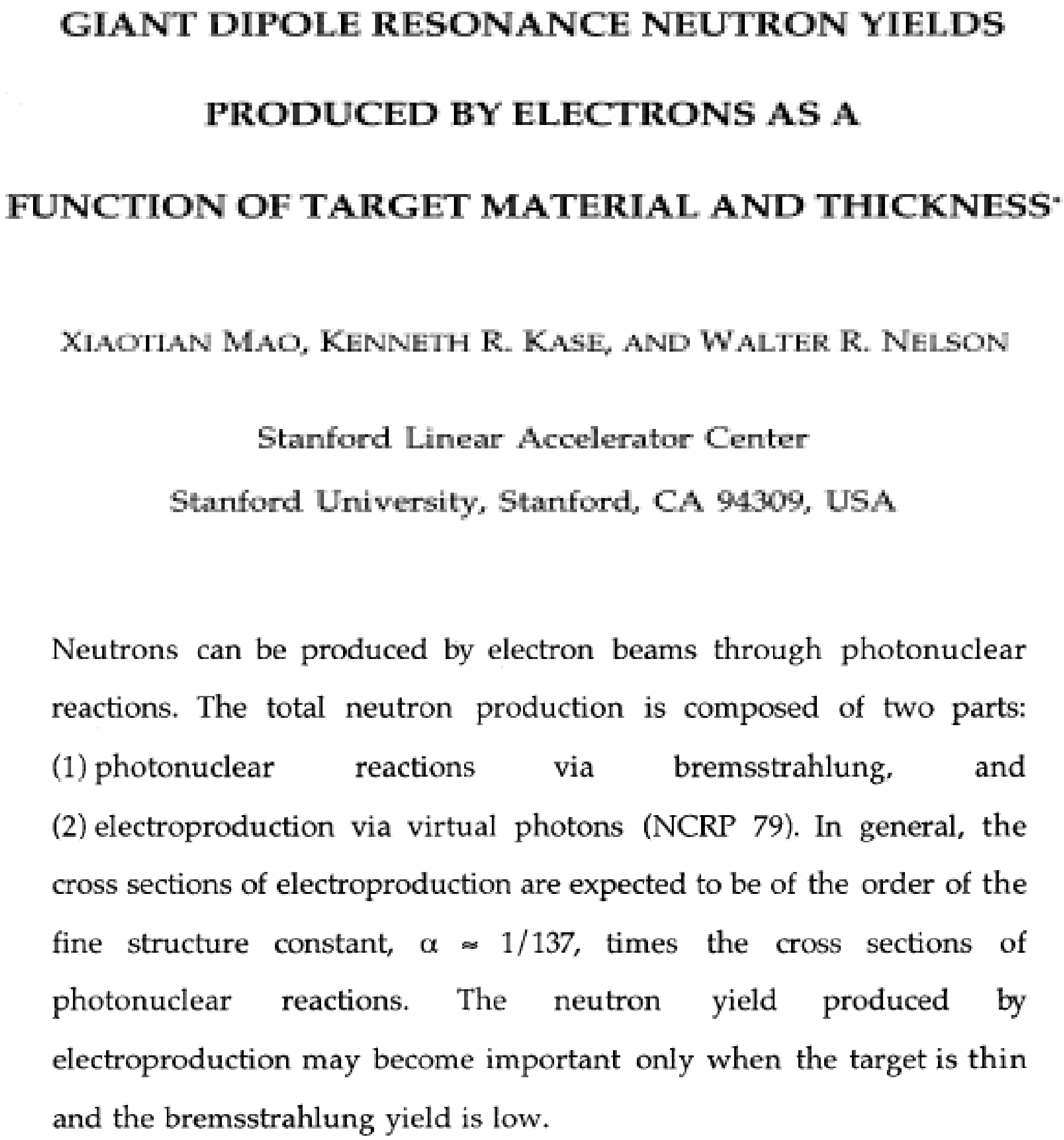
RSG-rotary spark-gap; DT-discharge tube; PM1 and PM2 -photomultipliers; OF-optical fiber; S1 and S2- scintilators; F-filter; K1 and A1- cathode and anode for pulsed discharge; PE preionization electrode; R1 = 10 kΩ, R2= 50 Ω, R3 = 10 MΩ, R4 = 1 MΩ, C = 3.3 nF; PT- pulse transformer 1:3; L1 = coaxial cable (l = 1 m) Z = 50 Ω, L2 = coaxial cable(l = 1 m) Z = 50 Ω,

- Project:
- - **Laser accelerated electron micro- beams coupled with dielectric fiber by Cruise Effect**

- Goals
- - Low divergence hard X-ray – source
- - Giant Dipolar Resonance studies
- - Activation of micro - fibers
- - Gamma-ray laser research
- - **Cruise Effect assisted polariton transport (Cruising Polariton)**

- Advantages:
- - pumping with very high intensity electron beam in a time ~ life time of the nuclear excited states of interest (in ps range)
- - electron micro-beams in plasmas (nC/J, 10-100MeV, fs-ps range)
- - avoiding of the heating or/and ablation for the interest material during the pumping by electrons or / and hard X-rays

Patent pending



# GIANT DIPOLE RESONANCE NEUTRON YIELDS PRODUCED BY ELECTRONS AS A FUNCTION OF TARGET MATERIAL AND THICKNESS*

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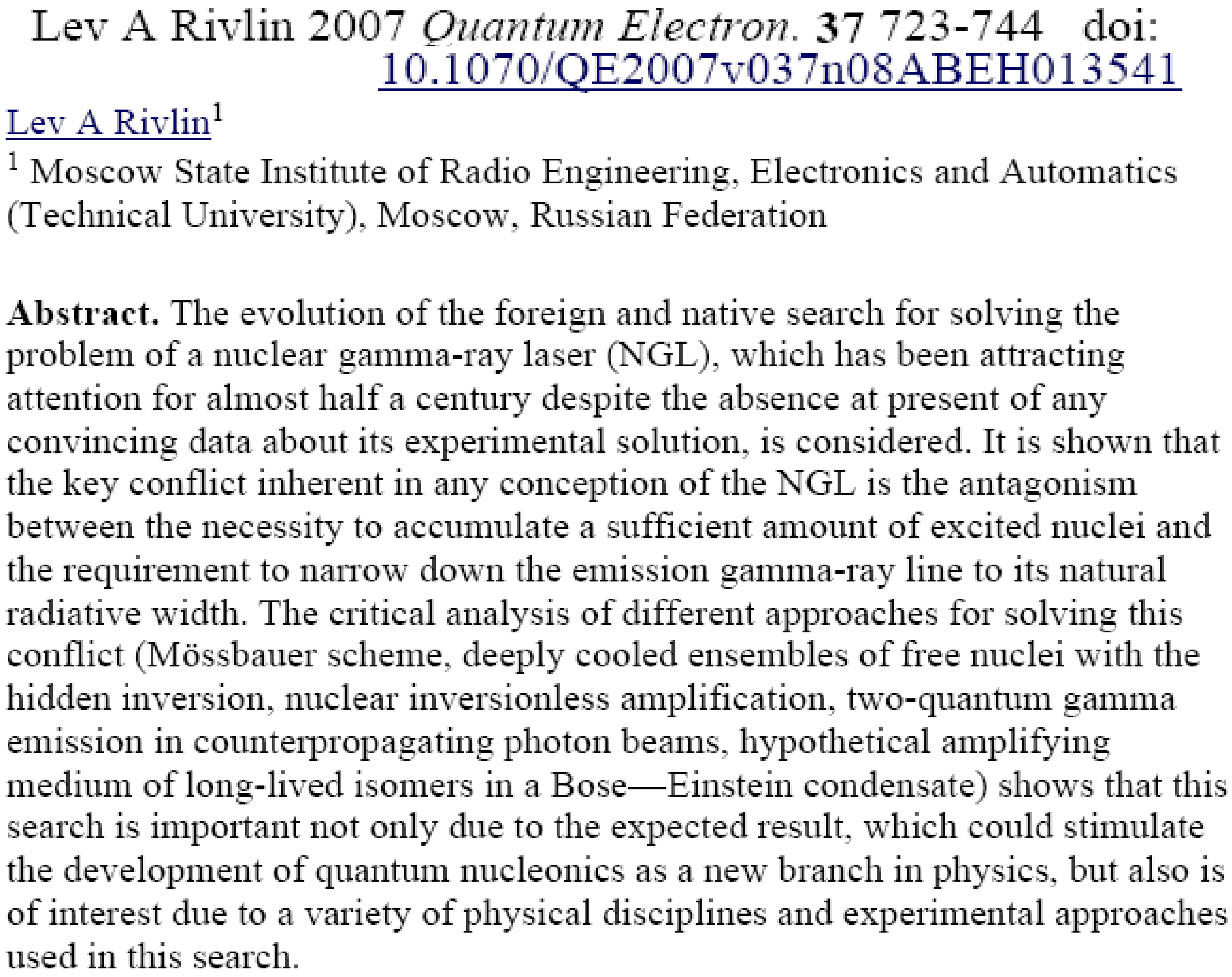
Neutrons can be produced by electron beams through photonuclear reactions. The total neutron production is composed of two parts: (1) photonuclear reactions via bremsstrahlung, and (2) electroproduction via virtual photons (NCRP 79). In general, the cross sections of electroproduction are expected to be of the order of the fine structure constant, $\alpha \approx 1/137$, times the cross sections of photonuclear reactions. The neutron yield produced by electroproduction may become important only when the target is thin and the bremsstrahlung yield is low.

# Nuclear gamma-ray laser: the evolution of the idea



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**Abstract.** The evolution of the foreign and native search for solving the problem of a nuclear gamma-ray laser (NGL), which has been attracting attention for almost half a century despite the absence at present of any convincing data about its experimental solution, is considered. It is shown that the key conflict inherent in any conception of the NGL is the antagonism between the necessity to accumulate a sufficient amount of excited nuclei and the requirement to narrow down the emission gamma-ray line to its natural radiative width. The critical analysis of different approaches for solving this conflict (Mössbauer scheme, deeply cooled ensembles of free nuclei with the hidden inversion, nuclear inversionless amplification, two-quantum gamma emission in counterpropagating photon beams, hypothetical amplifying medium of long-lived isomers in a Bose—Einstein condensate) shows that this search is important not only due to the expected result, which could stimulate the development of quantum nucleonics as a new branch in physics, but also is of interest due to a variety of physical disciplines and experimental approaches used in this search.

# Conclusions

- Polaritonic model – plasma assisted transport of the electrons synchronously with a high power laser pulse
- This kind of transport is in agreement with electron beam acceleration by bubble model
- Experimental validation by using TW lasers is proposed
- Cruise Effect could ensure strong coupling of laser accelerated electrons with dielectric target
    - New kind of directional hard X-ray sources
    - Activated micro-fibers
    - Gamma ray laser studies
    - Channeling studies
    - X-ray laser studies
    - New kind of electron – photon transport in polariton mode ?

# Thank you for your attention