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ELECTRON BEAM DIAGNOSIS AND DYNAMICS USING DIADYN'S PLASMA SOURCE

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This paper is presenting results obtained with the DIADYN installation after replacing its vacuum electron source (VES_LV) with a plasma electron source (PES_LV). DIADYN is low energy laboratory equipment operating with 10 to 50 keV electron beams and designed to help realize non-destructive diagnosis and dynamics for low energy electron beams but also to be used in future material irradiations. The results presented here regard the beam diagnosis and dynamics made with beams obtained from the newly replaced plasma source. We discuss both results obtained in experimental dynamics and dynamics calculation results for electron beams extracted from the PES_LV source.

Keywords: *electron beam, diagnosis, beam dynamics, low energy electrons*

EXPERIMENTAL SETUP

The beam system of DIADYN is presented in figure 1 and it consists of:

- The plasma source PES_LV, S
- The electron beam channel, EBC, made up of the magnetic lenses L1 and L2 and the field free spaces T1-T5
- A beam monitoring unit including two beam profile monitors M1 and M2 and the field free spaces T4, T5.

As one can see in figure 1 the vacuum electron source, VES [1], was replaced with an plasma electron source, **S**, with low voltage gas discharge, PES_LV, consisting of a discharge chamber vacuumed, and in which there is a cylindrical anode, **A**. The chamber has at its two ends two cathodes **K1, K2**, shaped as disks and on the same voltage. A discharge voltage, Ua, is applied between the two cathodes and the anode. An axial magnetic coil, Bs, surrounding the discharge chamber generates an axial magnetic field**.** An extraction electrode is placed at the bottom of the cathode, **K2**, in an extraction gap of the PES_LV source.

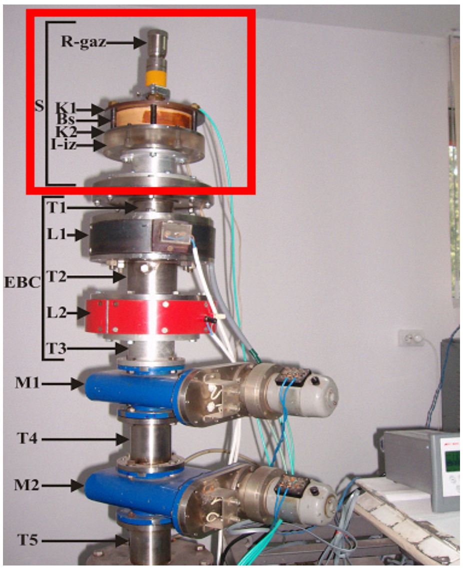


Figure 1: DIADIN equipped with the plasma source PES_JT.

BEAM DIAGNOSIS

The beam diagnosis method used for PES_LV electron beam characteristics determinations, is a non-destructive one, MTGM, priviously used for VES electron sources working in high, energy mode, [2,3].

When realizing the beam diagnosis in PES_LV regime both the pressure conditions in the extracting gap, and the transmitted current I_t, through EBC for an extraction voltage Ui_ex were taken into account. These conditions were the result of the discharge measurements in PES_LV, the current extraction from PES-LV and the transmission of this current through EBC. The important parameters that characterised the beam discharge-extraction-transmision system, in the beam diagnosis process are:

$P = \sim 2.10^{-5}$ *mbar ;Ua = 600V,* $I_d = 1A$, $I_{ex} = 0.24$ *A*, $I_t = 0.18$ *A ; Ui_ex = 12 kV*

The PES_LV parameters shown above are similar with the ones of a beam regime we have studied with the hot filament electron source, VES, working in a low energy mode [4]. This resemblance allows us to use for non-destructive diagnosis of the beam extracted from the PES-LV source the same method and the same program MTGM that we used in characterizing the VES sources.

The beam diagnosis for the PES_LV electron source was realized using the system made of the L1 lens and the two beam monitors M1 and M2 located after the EBC. We need to specify the electrical parameters of the L1 lens: L1 coil resistance, R_L1 = 3.8 Ω, L1 Amper -turns, NI_L1 = 710 At for I_L1 = 1 A, L1 coil current. Axial distribution of magnetic field in the EBC, was determined both experimentally and by computer simulations. For the functional point outlined above the maximum magnetic field in L1 lens results for example, Bc_L1 = 188gauss.

The determination of the beam parameters characterizing the spatial structure of the electron beam at the PES_LV exit are foregone by experimental measurements that consist of the determination of the experimental graphics RM1ex = f (UL1) and RM2ex = f (UL1). RM1ex and RM2ex are determined with the beam profile monitors.

In figure 2 we present a comparison between the experimental curves and the curves determined by calculations using as input data in the dynamics equation, [5] the beam parameters from table 1. The parameters of the discharge-extraction regime are: Ua=600 V, Ui_ex = 12kV, a- It = 0.18 A, b - It = 0.24 A.

Table 1: Beam parameters determined with MTGM applied to the electron beam extracted from PES_JT.

Experimental pulses read on M1	Beam parameters at Ui_ex = 12 kV		
	Eps [mm.mrad]	R0 [mm]	Z0 [mm]
"a", It=0.18A, RM1ex_base	30.8	6.32	57.82
"a1", It=0.18A, RM1ex_02h	**0.578**	**8.866**	**89.96**
"b", It=0.24A, RM1ex_base	150.99	11.53	0.02
"b1", It=0.24A, RM1ex_02h	0.833	14.58	4.36

Figure 2 shows the diagnosis of the beam extracted from PES_JT, and the experiment – calculation comparisons.

In this figure we can observe that the best concordance between the experimental determinations and the theoretical calculations, regarding the non-destructive diagnosis of the beam extracted from PES_LV, made using MTGM, can be obtained for case "a1" in table 1. This case corresponds to a transmitted current downstream from the L2 lens, with the intensity It = 0.18A and the energy W = 12 keV. The experimental pulses were determined in the “rms” (root mean square) sense with the M1 monitor and, particularly, for the case we discuss they were measured at 0,2h.

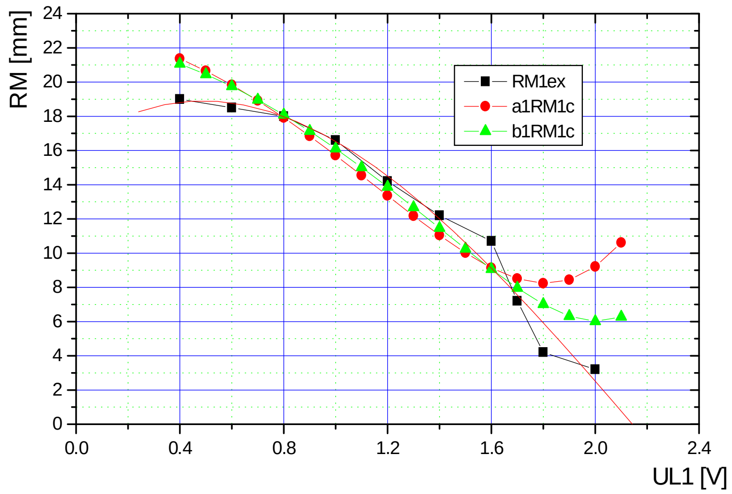


Figure 2: Experimental pulse measured at 0, 2 from the maximum amplitude.

EXPERIMENTAL BEAM DYNAMICS

In experimental dynamics we follow the same procedure as in experimental diagnosis [4]: the beam transversal sections are measured using the two beam monitors, M1 and M2 placed at Z=300 mm and Z=500 mm, the beam radii resulted from the experiment are calculated and then compared to the beam radii obtained from the beam dynamics calculations.

The pressure in the installation is measured with the gas cock closed and opened both with the PES_JT source lit and unlit. The pressure in the vacuumed installation is shown in table 2 as a function of the gas cock opening. P[div] = 0 means that the gas cock is closed. The discharge pulse in PES_JT for a pressure of $P = 2 \cdot 10^{-5}\, mbar$ is shown in figure 3.

Table 2: Discharge-extraction parameters in experimental dynamics.

PES_JT unlit					
P [div]	0	12	12.5	12.8	12.99
P [mbar]	1.1 10^{-5}	1.3.10^{-5}	1.5 10^{-5}	1.7 10^{-5}	1.9 10^{-5}
PES_JT lit: Ua = 600 V, Ub = 100 V~ , fr = 90 Hz, Id = 1.6 / 1 A					
P [div]	12.8	12.99			
P [mbar]	1.8 10^{-5}	2.0 10^{-5}			
PES_JT lit, extraction voltage applied Uî_a = 15 kV, Uî_ex = 11 kV , Ub =100 V~			PES_JT lit, extraction voltage applied Uî_a = 15 kV, Uî_ex = 12 kV, Ub =80 V~		
P [div]	12.99		12.99		
P [mbar]	2.7 10^{-5}		2.6 10^{-5}		

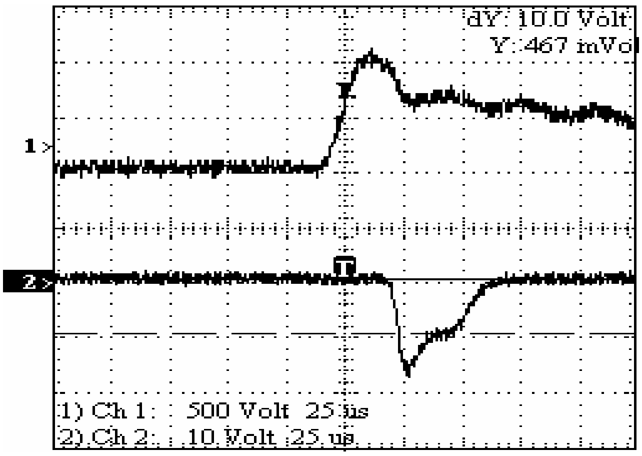
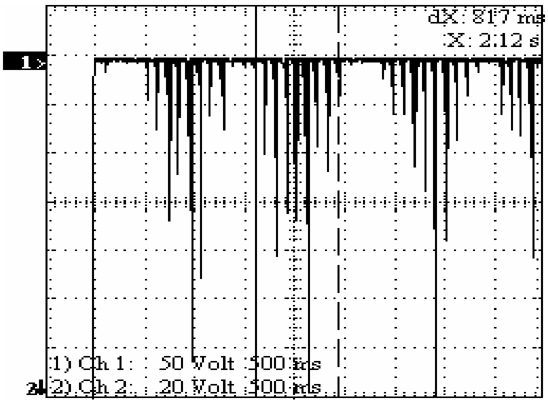


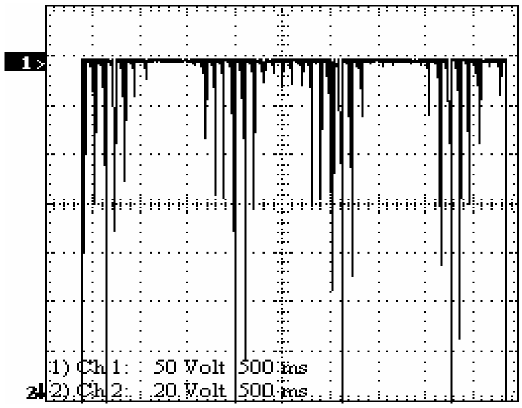
Figure 3: Initial discharge pulse in experimental dynamics measurements.

As we can see the figure 3, for the pressure $P = 12{,}99 div$ at the gas cock (equal to $P = 2 \cdot 10^{-5}\, mbar$), the discharge current was Id=1,6A/1A. This initial current was obtained for the following discharge parameters: Ua=600V, Ub=100V, fr=90Hz. Applying the high voltage Ui_a=15kV led to an increase of the pressure in the vacuumed installation up to $P = 2{,}7 \cdot 10^{-7}\, mbar$ and a high voltage in the extraction interval of 11kV

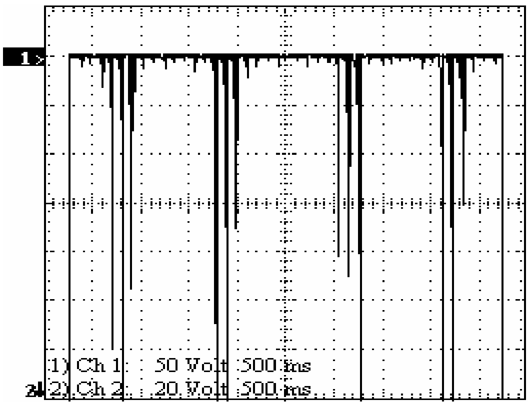
In figure 4 it is presented the evolution of the beam pulse duration that shows the transversal beam section downstream from CFE at the M1 beam monitor level, as a function of the beam channel regime. The input data of the beam current in CFE are given in table 2. The functioning regimes of the beam channel are chosen for the lens voltages UL1=1V while UL2 is variable. One can observe that the beam pulse period at the beam monitor M1 level (that is the beam transversal section) decreases proportionally with the L2 lens power (which is also proportional to UL2). The transversal section of the beam reaches its lowest values at the M1 level for UL2 values situated between 4,4V and 4,8V. For a UL2 voltage above 5V the transversal section starts increasing which shows that the image cross-over position is moved upstream from M1.



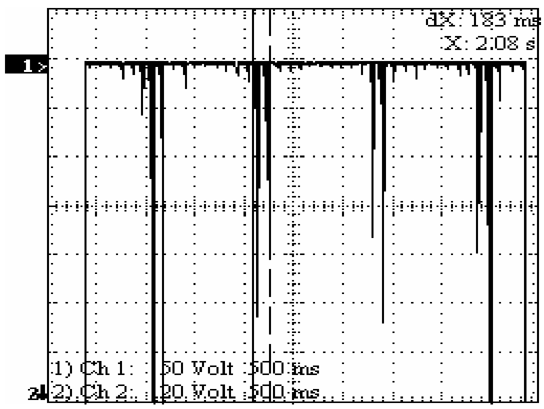
UL1 = 1V, UL2 = 0 V



UL1 = 1 V, UL2 = 2 V



UL1 = 1 V, UL2 = 3.8 V



UL1 = 1 V, UL2 = 4.2 V

Figure 4: Experimental dynamics on DIADYN for an electron beam extracted from PES_JT.

CALCULATED BEAM DYNAMICS

The calculated beam dynamics data as well as the experimental data obtained by measuring the beam transversal section at the M1 and M2 monitor levels were far more numerous than the ones presented in this paper. In figure 5 it is presented a comparison between the calculus data obtained with the TRAJ program and the experimental data measured with the beam monitors. The comparison is made for the functioning regimes of the CFE for which UL1=1V and UL2 takes values between 0V and 6V.

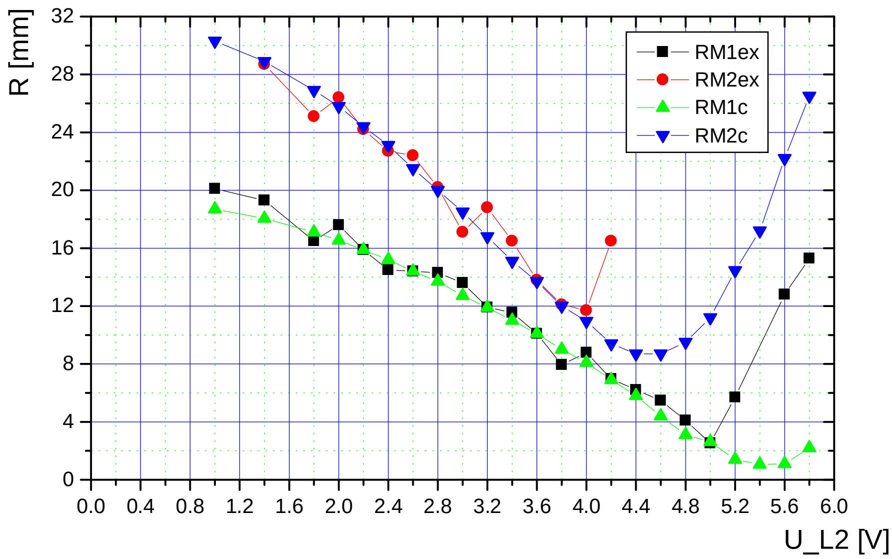


Figure 5: Comparison between the calculated and the experimental dynamics data UL1 = 1V, UL2 variable.

One can see in figure 5 that the experimental data don't differ very much from the calculated data which can entitle us to say that the characteristic beam parameters were correctly determined with MTGM [5]. This allows us to trust the calculated data (using the same beam parameters) for other functioning regimes of the beam channel.
In figure 6 the beam dynamics for the lens voltages UL1=2V and UL2 variable is shown. The rest of the conditions are given in table 1 for N=2.

Regarding the discussion of the calculated dynamics data, examining the experimental data presented in figure 5 underlines a sudden scattering of the beam downstream from the image crossover, the point corresponding to UL2=5V for the beam measured with the M1 monitor (Z=300mm) and the point corresponding to UL2=4V for the beam measured with the M2 monitor (Z=500mm). The increase of the UL2 voltage above these values leads to disaccord between the calculated data and the experimental data which means that the calculated data no longer have practical use.

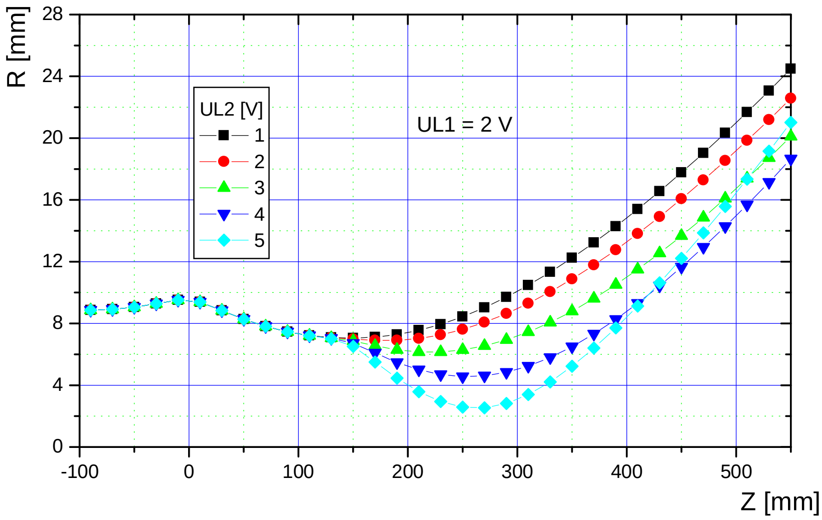


Figure 6: Calculated dynamics for an electron beam extracted from PES_JT; UL1=2V, UL2 variable.

CONCLUSIONS

The paper presented the electron beam diagnosis and dynamics results obtained with the DIADYN, a low energy equipment. At first a brief presentation of the installation is given, mainly to describe the new source, PES_JT that is functioning now on the installation. The conditions in which electron beam diagnosis was made and the results obtained in these conditions are given in the paper. It has to be underlined that the experimental determinations are in good concordance with the theoretical calculations. It has been shown that the pressure in the installation is very important and it has a great influence on the diagnosis and dynamics experiments. A comparison between the experimental and the calculated dynamics shows that these are in good concordance also.

The MTGM method was used in characterizing the electron beam extracted from SEP_JT with the beam current approximately 0,2A and the energy of 12 keV. This beam was transmitted downstream from CFE without major current loss and the theoretical dynamics realized with the TRAJ program was verified by the experimental dynamics determinations. More theoretical and experimental research is needed to optimize the electron beam extraction system of the PES_LV source. We worked in a low energy regime and using low discharge current (bellow 1A) comparing to the ones (1A to 5A) we could have obtained in these conditions.

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