

BEAM DIAGNOSIS AND DYNAMICS IN A HIGH ENERGY MODE OF THE DIADYN LABORATORY EQUIPMENT

D. Toader¹, S. Maghitu², C. Oproiu¹, O. Marghitu³

¹ *National Institute for Lasers Plasma and Radiation Physics, Bucharest, Romania*

² *ICPE Electrostatica, Bucharest, Romania*

³ *Institute for Space Sciences, Bucharest, Romania*

Abstract

DIADYN, a low energy laboratory equipment, is used to realize non-destructive diagnosis and beam dynamics for low energy electron beams. Typically, DIADYN is operated below 30 keV beam energy. Here we concentrate on results obtained during recent experiments, conducted at 32 keV beam energy, in a high energy mode of the DIADYN installation. The outcome of the beam diagnosis, realized by the modified three gradient method (MTGM), emphasizes the need to take into account the root-mean-square beam radius. For the beam dynamics, the image cross-over should be located behind the target plane, in order to obtain a good agreement between computed and measured beam radii.

1. Introduction

The DIADYN installation represents an equipment realised for the elaboration and testing of the MTGM method and for beam dynamics investigations, [1], [2], [3], of low energy (10-50keV), intense electron beams. Equipped with a hot filament vacuum electron source (VES), the installation was tested at 32 keV, and the results were used to check the non-destructive diagnosis and beam dynamics in this high energy mode of the DIADYN installation. For these experiments we selected a high voltage, U_i , of 32 kV, and a heating voltage of the filament, U_{fil} , of 7.6 V, or 20 div in arbitrary units. Under these conditions, the current extracted from the source, I_a , was 220mA, measured on a 10 Ω resistance and collected with a Faraday cup placed near the anode.

2. Experimental Setup

The beam system, (a), and part of the vacuum system,(b), of the Installation DIADYN are presented in figure 1. The beam system consists of:

- A pulsed Pierce diode electron source, **S**, providing 4 μ s beams, at 100 Hz, with I and U in the ranges 0.05–1A and 10–50keV.
- The electron beam channel, **EBC**, made up of the magnetic lenses **L1**, **L2**, and the field free spaces **T1–T5**; The vacuum room, **VR**.
- A beam monitoring unit, including two beam profile monitors **M1**, **M2**, a sliding Faraday cage (parked inside VR), and the HV probe, **HVP**.

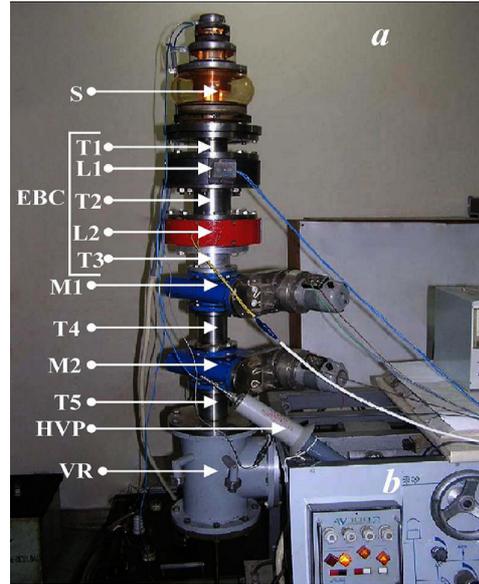


Fig. 1 The DIADYN equipment

3. Experiments and results

The electrical parameters of the source are the extraction high voltage, U_i , that determines *the energy of the beam*, the heating voltage of the filament, U_{fil} , and the beam current, I_a , which depends on both the high voltage and the heating voltage. The electron beam extracted from the source forms a minimum named object cross-over. Axially symmetric beams are defined by three parameters: the beam emittance, ϵ , the cross-over radius, R_o , and the cross-over position, Z_o , with respect to the lens L1. The values of these parameters depend on the geometry of the source and on the electrical functioning point.

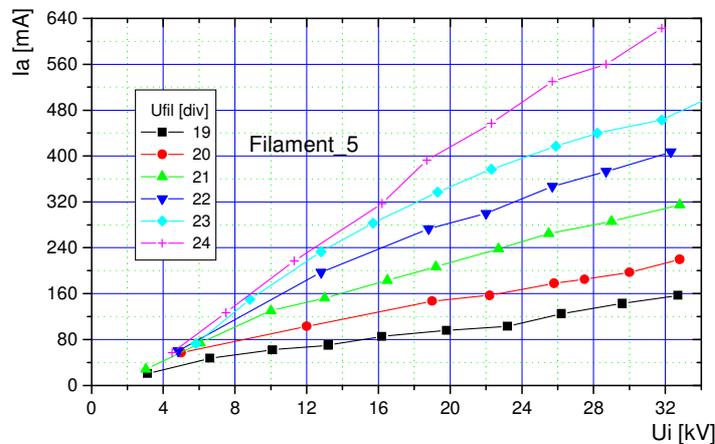


Fig. 2
Functioning points of the DIADYN source.

The functioning point used in the following for the diagnosis and dynamics is at $I_a = 220$ mA, $U_i = 32$ kV, and $U_{fil} = 7.6$ V. Figure 2 shows the beam current near the anode as a function of the high voltage U_i , for different heating voltages U_{fil} . The selected functioning point is close to the last dot on the red curve.

The diagnosis results for this functioning point are presented in Fig. 3. The experimental curves $RM1_{ex} = f(UL1)$ and $RM2_{ex} = f(UL1)$ show the dependence of the beam radius on the voltage applied to the lens L1. This voltage determines the magnetic field created by the lens and, consequently, the position of the lens main plane and its focal distance. The beam parameters derived by MTGM are listed in Table 1.

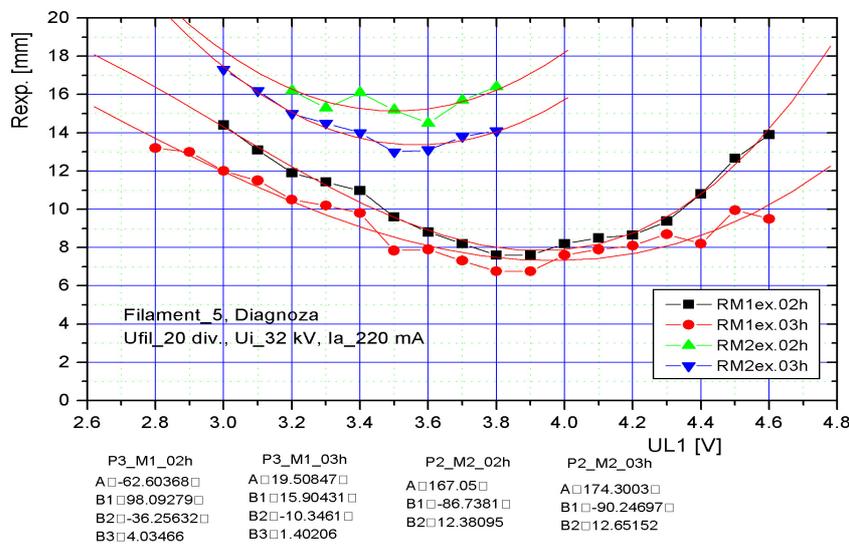


Fig. 3
Beam diagnosis at
 $U_i = 32$ kV, $U_{fil} = 7.6$ V,
 $I_a = 220$ mA

Table 1 Beam parameters determined by MTGM

	ϵ (mm.mrad)	R0 (mm)	Z0 (mm)	p1	p2
Nc_03h	112.2	2.34	111.54	1	0
Nb_02h	109.4	2.78	114.98	0	1

The two sets of beam parameters, with similar values, are determined at the exit of the electron source. When $p1=1$, $p2=0$, we use only the experimental data measured by the monitor M1, at 0.3h, that is at 0.3 from the maximum pulse amplitude, h. In the second line, $p1=0$, $p2=1$, we use the data measured by the monitor M2, at 0.2h. The maximum value of the beam cross-section is at 0.0h.

The computed beam dynamics, based on the parameters derived from M1 data, is presented in Fig. 4. We show five different beam envelopes, corresponding to five different EBC regimes, with $NI_{L1}=600$ At and NI_{L2} from 205 to 924 At, as indicated in the figure.

Figure 5 shows experimental data for the beam dynamics, used for comparison with the computed data. The beam radius is derived at two locations, from the duration of the pulse recorded with monitor M1, at $z = 300$ mm (channel 1), and with monitor M2, at $z = 500$ mm (channel 2). Panel "a" corresponds to $NI_L2 = 205$ As (to be compared with the black curve in Fig. 4), while panel "b" corresponds to $NI_L2 = 616$ As (to be compared with the green curve in Fig. 4).

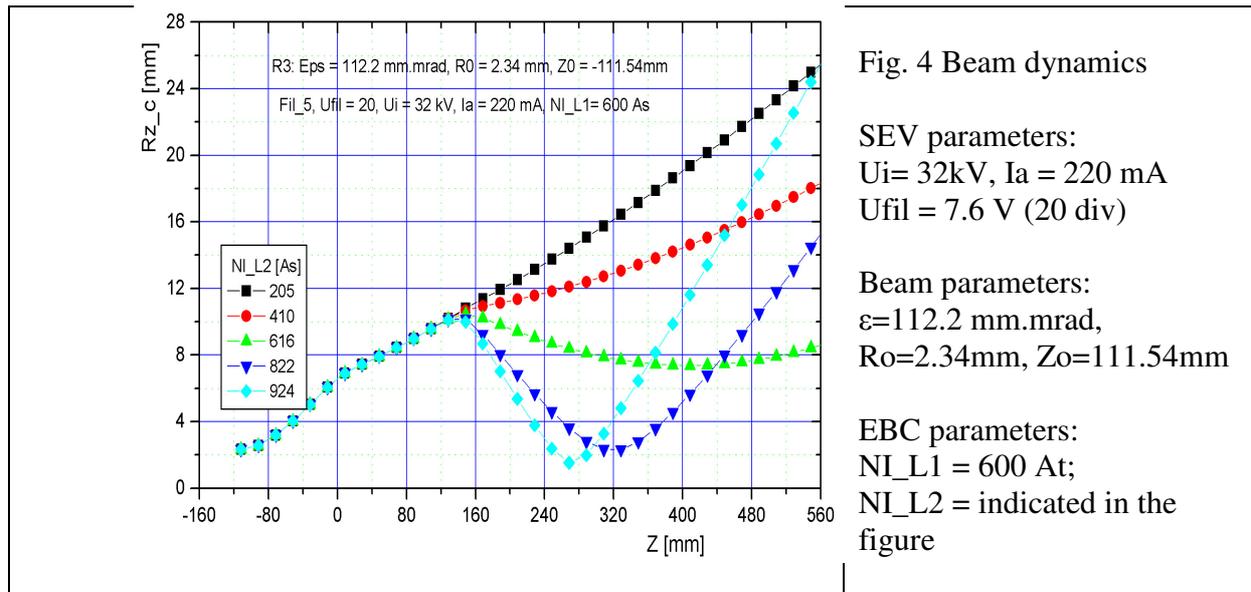


Table 2 summarizes the comparison between the computed and measured beam dynamics results. At the monitor M1 the calculated beam radius is almost identical with the measured one for three values of NI_L2 (205, 410, and 616 At), while at monitor M2 there is good agreement between the calculated and measured radii for two values of NI_L2 (205 and 410 At). When the image cross-over comes in front of the monitor, the computed and measured radii are no longer similar, presumably because the paraxial approximation, assumed in the computations, is no longer valid.

Table 2 Beam dynamics calculations versus experimental results

$I_a = 220$ mA, $U_i = 32$ kV, $\epsilon = 112.2$ mm.mrad, $R_o = 2.34$ mm, $Z_o = 111.54$ mm					
U_L2 [V]	2	4	6	8	9
NI_L2 [As]	205	410	616	822	924
Rc / Rex M1	15.7/15.5	12.7/12.2	7.9/8.1	2.33/>25mm	3.28/>25mm
Rc / Rex M2	22.5/22.9	16.2/16.2	8/>25mm	11/>25mm	19/>25mm

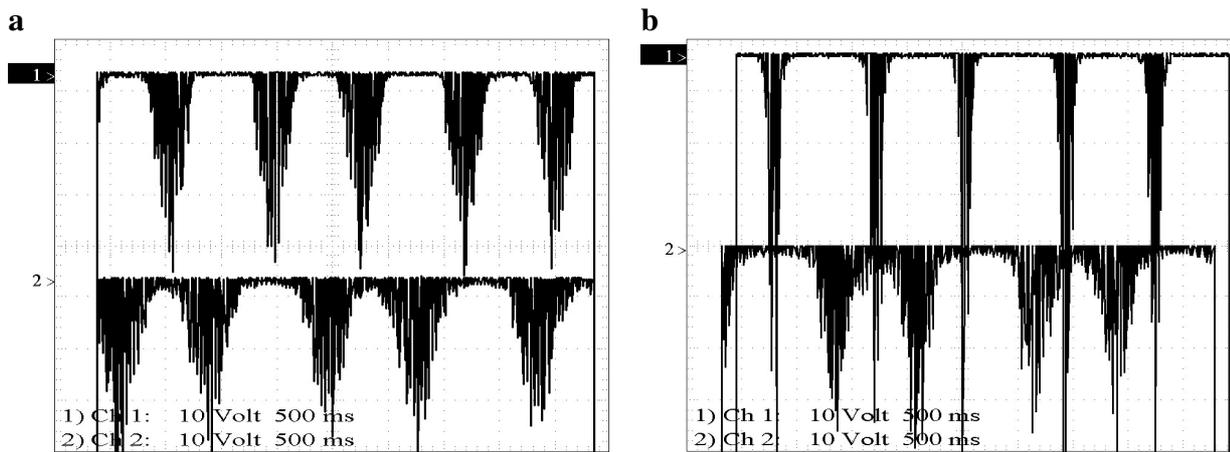


Fig. 5. Pulses showing the beam dynamics process at NI_L1=600At with
 (a) NI_L2 =205At and (b) NI_L2 =616At

4. Conclusions

The DIADYN equipment can operate properly at higher energies than those used so far. As already noticed in the lower energy experiments, in order to obtain consistent diagnosis results, the radius of the beam cross-section has to be considered in the root mean square sense. For the beam dynamics, the agreement between the calculated and the measured data is good only as long as the calculated image cross-over remains behind the monitor position, or equivalently, behind the target plane. More experiments are needed to determine which functioning points of the VES and EBC regimes are better suited for particular applications of DIADYN in probe irradiation experiments.

References

1. S. Marghitu, O. Marghitu, C. Oproiu, G. Marin, and F. Scarlat, Nucl. Instr. Meth. B 217 (2004), 498 – 504.
2. S. Marghitu, O. Marghitu, M. Rizea, C. Oproiu, M. Vasiliu, Proc. 8th Int. Conf. on Electron Beam Technologies, Varna, Bulgaria, in Elektrotehnika i Elektronika, E + E, Nr. 5-6, 276 – 280, 2006.
3. S. Marghitu, C. Matei, C. Oproiu, O. Marghitu, D. Toader, Analele Univ. de Vest, Timișoara, Seria Fizică, 49, 97 – 101, 2007.