Experimental Research on Double Pulsed Relativistic Electron Beams Emission from Velvet *

XIA Lian-Sheng LI Jin ZHANG Huang XIE Yu-Tong JIANG Xiao-Guo DAI Zhi-Yong
ZHANG Kai-Zhi SHI Jin-Shui DENG Jian-Jun ZHANG Lin-Wen

(Institute of Fluid Physics, CAEP, Mianyang 621900, China)

Abstract The double pulsed electron beams' characteristics such as the movement position, the beams spot and the emittance were experimentally studied in the time-resolved mode. In the experiments, beam bugs were used to detect the beam currents and the beam positions, and the Cerenkov radiation generated by the electron beams interacting with a quartz plate was used to get the information of the beams. The radiation was recorded by an 8 film streak camera. The experimental results indicate that the double pulsed relativistic beams emission from velvet has almost the same centroid movement, the same beam spots and the same emittances. The vacuum diode voltages are 1.75MV and the beam currents are about 1kA.

Key words velvet cathode, double pulsed beams centroid, emittance, time-resolved mode

1 Introduction

As a kind of cheap and easily available cathode, velvet can emit high current electron beam with a brightness up to 10^8A/(m·rad)^2 and is widely used in high pulsed power research field. So the devices such as ARIX[1] and DARHT-I[2] use the velvet to produce a few kilo-ampere pulsed beam. The beam pulse duration is around 100ns. Some papers[1—5] have described the velvet's emission and diode characteristics in a single-pulsed mode. However, there are still some questions remained to answer. Can the cathode work in the multi-pulsed mode? How about the beam quality? What are the factors which can affect the beam quality emitted from velvet? The authors have built up a multi-pulsed power source and a multi-pulsed diode to undertake some research on the velvet's emission characteristics[6—8]. In this paper, the authors like to introduce some recent experimental results of the double pulsed beams. The beams are generated from a double pulsed vacuum diode. The diode voltages are 1.75MV and the pulse duration (FWHM) is 90ns. The electron beam currents emitted from the velvet cathode with the radius of 3.5cm are about 1.2kA. The doubled beams transmit along the beam line and are confined by an extra magnetic field. The beams' characteristics such as the centroid movement, the beams spot and the emittance were experimentally studied in the time-resolved mode. In the experiments, the resistive wall monitors known as beam bugs[9, 10] were used to detect the beams current and the beams centroid movement, and the Cerenkov radiation generated by the electron beam interaction with a quartz plate was used to get the information of the beams' profile and transverse velocity. The radiation was recorded by an 8 film streak camera. Beam bugs are placed at 3.6m downstream. The pepper pot used to measure the emittance is placed at 3.9m downstream and the quartz plate is placed at 4.1m downstream (see Fig. 1).

Received 1 November 2006, Revised 23 December 2006

* Supported by National Nature Science Foundation of China (10575090) and Science Foundation of China Academy of Engineer Physics (20050209)

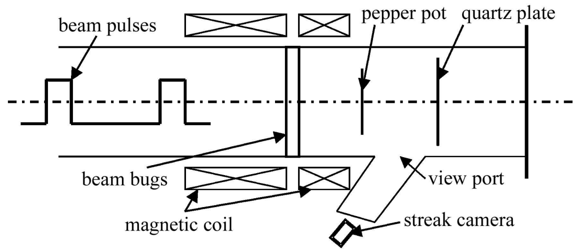

Fig. 1. Sketch of the measurement system.

2 Beam current and centroid movement

The beam bugs are used as essential diagnostics of the beam current and centroid movement. When the doubled beams are emitted from the cathode, they are confined by extra applied solenoid magnetic field and transmitted along the beam line. Defining a Cartesian coordinate system facing the cathode and making the origin of the coordinates on the beam line, one can determine the beams current and positions of the beams' centroids at the place of beam bugs in the coordinates. Fig. 2(a) gives the results of the beams' currents, and it is about 1kA. Figs. 2(b), 2(c)

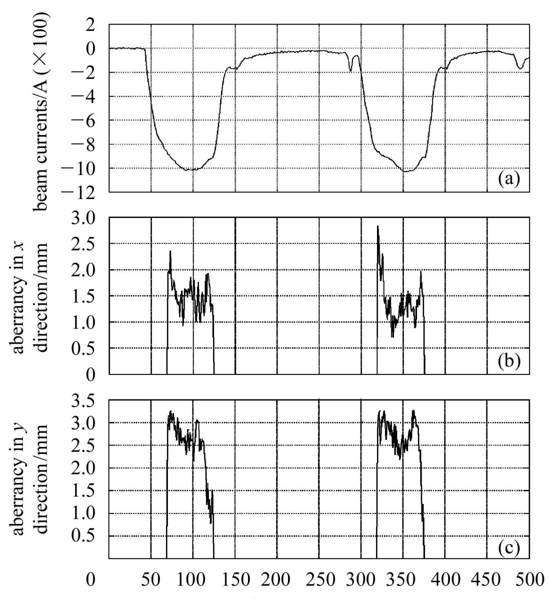

Fig. 2. The beam currents (a) and centriod aberrancy in x(b) and y(c) direction respectively.

give the beams' centroid positions in 55ns duration in the coordinate. Even no special work was done on the adjustment of solenoid magnetic field in the diode and on the beam line , the beams centroid position departs from the origin of the coordinate less than 5mm in the x and y direction respectively. This result offers the possibility of further more refined adjustment of the beams' centroid movement. The burrs in Figs. 2(b), 2(c) are the noise generated in the numerical process.

3 Double pulsed beams' spots

The beams' spots were detected by the Cerenkov radiation generated by the beams interacting with a quartz. In this process, the pepper pot was removed and the quartz plate was kept (Ref. to Fig. 1). The radiation was recorded by the streak camera. When the beams are free from the magnetic field after they pass the beam bugs, the beams spots in a shot are shown in Fig. 3. The diameters (FWHM) of the spots are about 65mm. This result is obviously different from that the authors once gave in another paper[10]. In the experiment described in the paper[11], the diode voltages are about 0.6MV and the diode gap is 5cm. The cathode plasma seriously affects the second electron beam emission. However, in the experiment described in this paper, the diode voltages are 1.75MV, and the diode gap is 15.5cm. So the cathode plasma has a little effect on the second emission.

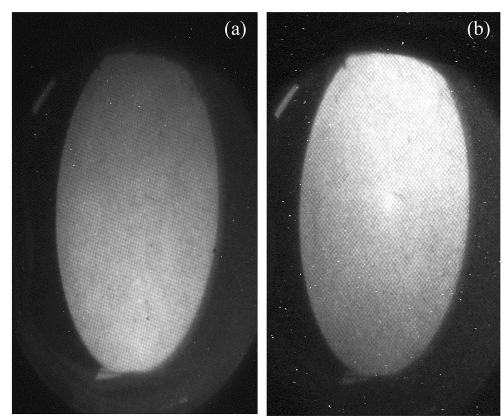

Fig. 3. The first (a) and the second (b) beam spots free from magnetic field.

When the beams are confined by magnetic field while they interact with the quartz plate, the beam spots are much small than that in Fig. 3. Fig. 4 is the time resolved beam spots for the first and the second beam respectively. The diameters (FWHM) are about 20mm. From Fig. 3 and Fig. 4, one can find that the two beams have almost the same diameters at the same detecting position. That means the two beams have the same envelope at the same magnetic field.

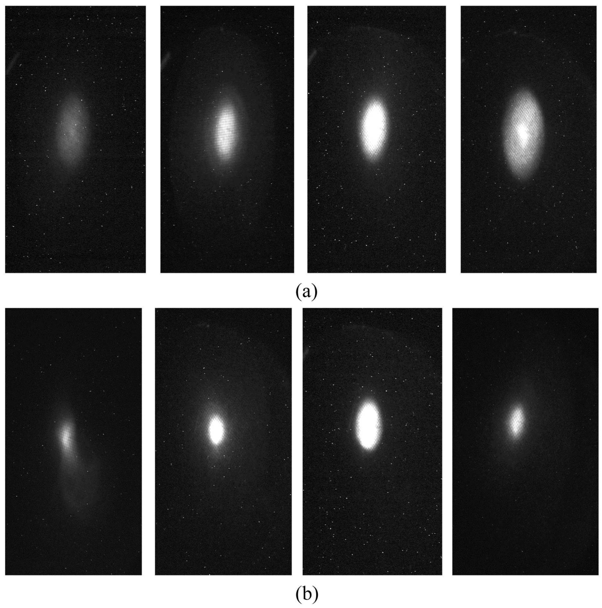

Fig. 4. The first (a) and the second (b) beam spots with magnetic field.

4 Beams emittance

Two methods are used to check the emittance difference of the double pulsed beams. One is the magnetic collimator and the other is pepper pot.

Table 1 is the current of the doubled beams under different magnetic fields. The electron beam currents are recorded by the beam bugs. From Table 1, one can see the differences between the doubled beams currents under different magnetic fields are less than 2%. According to the results, one can conclude that the doubled beams' emittances are almost the same.

Table 1. The beam currents under different magnetic fields.

serial number	the first beam current/A	the second beam current/A
16463	1020	1030
16464	910	930
16465	870	880
16466	780	770
16467	600	590

In the experiment of using pepper pot to measure the beams time resolved emittance, Cerenkov radiation generated by the beamlets interacting with quartz is used to determine the beams transverse velocity. The radiation was recorded by the streak camera. Fig. 5(a) and Fig. 6(a) are the photo for the first and the second beam at the same magnetic field respectively. Fig. 5(b) and Fig. 6(b) are the black density scans of the Fig. 5(a) and Fig. 6(a) respectively in the vertical direction. So one can see that the beams' envelopes are in gaussian distribution. Making gauss fit one can figure out the beams' time resolved emittance. Fig. 5(c) is the time resolved emittance for the first beam in 70ns, and Fig. 6(c) is for the second beam.

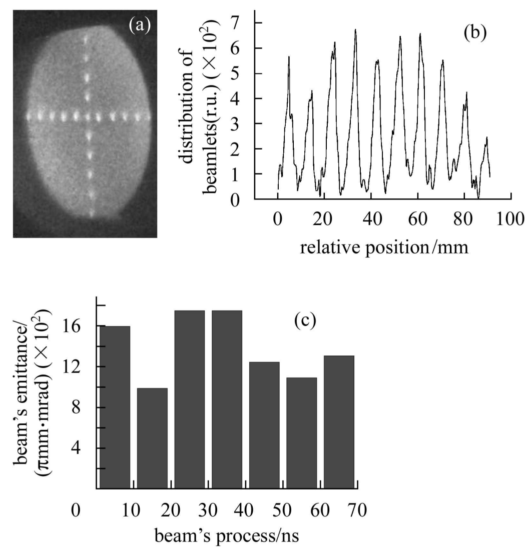

Fig. 5. The first beam pepper pot photo (a), distribution of density (b) and time resolved emittance (c).

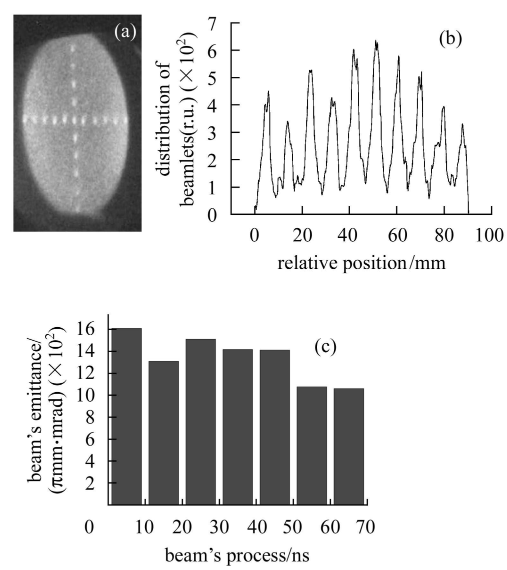

Fig. 6. The second beam pepper pot photo (a), distribution of density (b) and time resolved emittance (c).

From Fig. 5(c) and Fig. 6(c), one can see that the doubled beams have similar emttance and are around 1500πmm·mrad. Considering the results of the magnetic collimator, one can conclude that the double pulsed beams have similar brightness.

5 Conclusion

When the diode voltages are 1.75MV and the diode gap is 15.5cm, the doubled pulsed relativistic electron beams emitted from velvet have almost the same centroid movement, the same envelope and the same emittance, which are more exciting than the results of the paper[11]. The cathode plasma has little effect on the qualities of the second beam. One can expect that with higher diode voltages and a larger diode gap the cathode plasma will have even less effect on the qualities of the second beam and the qualities of the double beams are much more identical.

References

1 Merle E, Boivinet R, Mouillet M et al. Proc. of Particle Accelerator Conference. New York: IEEE, 1999. 3260—3262

2 Burns M, Carlsten B, Kwan T et al. Proc. of Particle Accelerator Conf.. New York: IEEE, 1999. 617—621

3 Miller R B. J. Appl. Phys., 1997, **84**: 3880—3889

4 Shiffler D A, Lacour M, Golby K et al. IEEE Transactions on Plasma Science, 2001, **29**: 445

5 LIU G Z. Chinese Physics, 2005, **14**: 949—952

6 XIA L S, ZHANG H, CHEN D B et al. Chinese Physics, 2005,**14**: 1779

7 XIA L S, ZHANG K Z, SHI J S et al. Applied Surface Science, 2005, **251**: 262—265

8 XIA L S, WANG M, HUANG Z P et al. Acta Phys. Sin, 2004, **53**: 3435—3439 (in Chinese)
(夏连胜等. 物理学报, 2004, **53**: 3435—3439)

9 XIE Y T et al. High Power Laser and Particle Beams, 2002, **14**: 151 (in Chinese)
(谢宇彤等. 强激光与粒子束, 2002, **14**: 151)

10 CHEN Y J, Fessenden T J. XIX int. Linac Conf. Illinois:IEEE, 1998. 189

11 XIA L S et al. High Power Laser and Particle Beams, 2005, **17**: 1897 (in Chinese)
(夏连胜等. 强激光与粒子束, 2005, **17**: 1897)

天鹅绒阴极产生的双脉冲强流相对论电子束特性实验研究*

夏连胜　李劲　张篁　谢宇彤　江孝国　代志勇
张开志　石金水　邓建军　章林文

(中国工程物理研究院流体物理研究所　绵阳　621900)

摘要 在时间分辨的模式下, 实验研究了天鹅绒阴极产生的双脉冲相对论强流电子束的束心运动、束包络和束的发射度. 在实验中, 电子束流强度和电子束心运动用电阻环进行测试, 而电子束和石英玻璃的相互作用产生的契仑科夫辐射用来给出电子束包络和发射度信息. 电子束和石英玻璃作用产生的契仑科夫辐射用 1 台 8 幅分幅相机记录. 实验结果表明, 天鹅绒阴极产生的相对论强流双脉冲电子束在束流大小、束心运动轨迹、束包络及束发射度等方面具有较好的一致性.

关键词 天鹅绒阴极　双脉冲电子束束心运动　发射度　时间分辨模式

2006 – 11 – 01 收稿，2006 – 12 – 23 收修改稿
∗ 国家自然科学基金 (10575090) 和中国工程物理研究院科学基金 (20050209) 资助