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Multi-Monitor Emittance Measurement in the IR Demo Driver

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Abstract
We describe and give results for a multi-monitor emittance measurement performed using the IR Demo driver.

Overview
The backleg region of the IR Demo driver accelerator nominally comprises six periods of 90° FODO beam transport line. The excitations of the 13 quadrupoles therein are modulated (by order 5%) from ¼ integer tune values to maintain a transverse beam envelope match from endloop to endloop while maintaining a (modulo) ½ integer phase advance, which provides useful aberration suppression. A list of quadrupole names and nominal excitations for 48 MeV (3 μm) operation is provided in Table 1.

This region is instrumented with six optical transition radiation (OTR) monitors. These are adjacent to quadrupoles QG4F05 through QG4F10 and can in principle be used with the nominally excited quadrupoles to perform an emittance measurement of the type regularly used in the CEBAF injector [1]. The measurement presently under consideration was however performed as a portion of a broader investigation, the purpose of which is to develop "single-quad/monitor" measurements [2] for use in Demo CSR investigations [3]. Quadrupoles QG4F05 through QG4F13 were therefore unexcited; QG4F01 through QG4F04 were adjusted in an effort to produce simultaneous minima in horizontal and vertical spot sizes in the vicinity of viewer ITV4F07 or ITV4F08 as QG4F05 was varied. This goal has not yet been successfully attained, but the quadrupole excitations developed in the process did produce well-modulated beam sizes on all six OTRs, providing the potential for a readily deconvoluted emittance measurement.

Table 1: IR Demo Backleg Quadrupole Excitations

Name	Nominal 3 μm Excitation (gradient integral, G)	Measurement Excitation (gradient integral, G)
QG4F01	167.6	-200
QG4F02	787.2	650
QG4F03	-822.0	-750
QG4F04	851.8	500
QG4F05	-822.6	0
QG4F06	822.6	0
QG4F07	-822.6	0
QG4F08	822.6	0
QG4F09	-822.6	0
QG4F10	851.8	0
QG4F11	-822.0	0
QG4F12	787.2	0
QG4F13	167.6	0

Results

On 29 September 2000, viewer images from ITV4F05 through ITV4F10 were taken on the IR Demo Driver using a 3 μm configuration (all-save 575), Table 1 "Measurement Excitation" quad settings, and 60 pC beam (Figure 1). Alas, incompetence of the operator (your faithful narrator) precluded acquisition of quantitative profile data using the MaxVideo; inasmuch as the machine reproduces well the setup is recoverable and this data fortunately can be acquired at a later date. At present we are however limited to an analysis of the viewer images shown below.

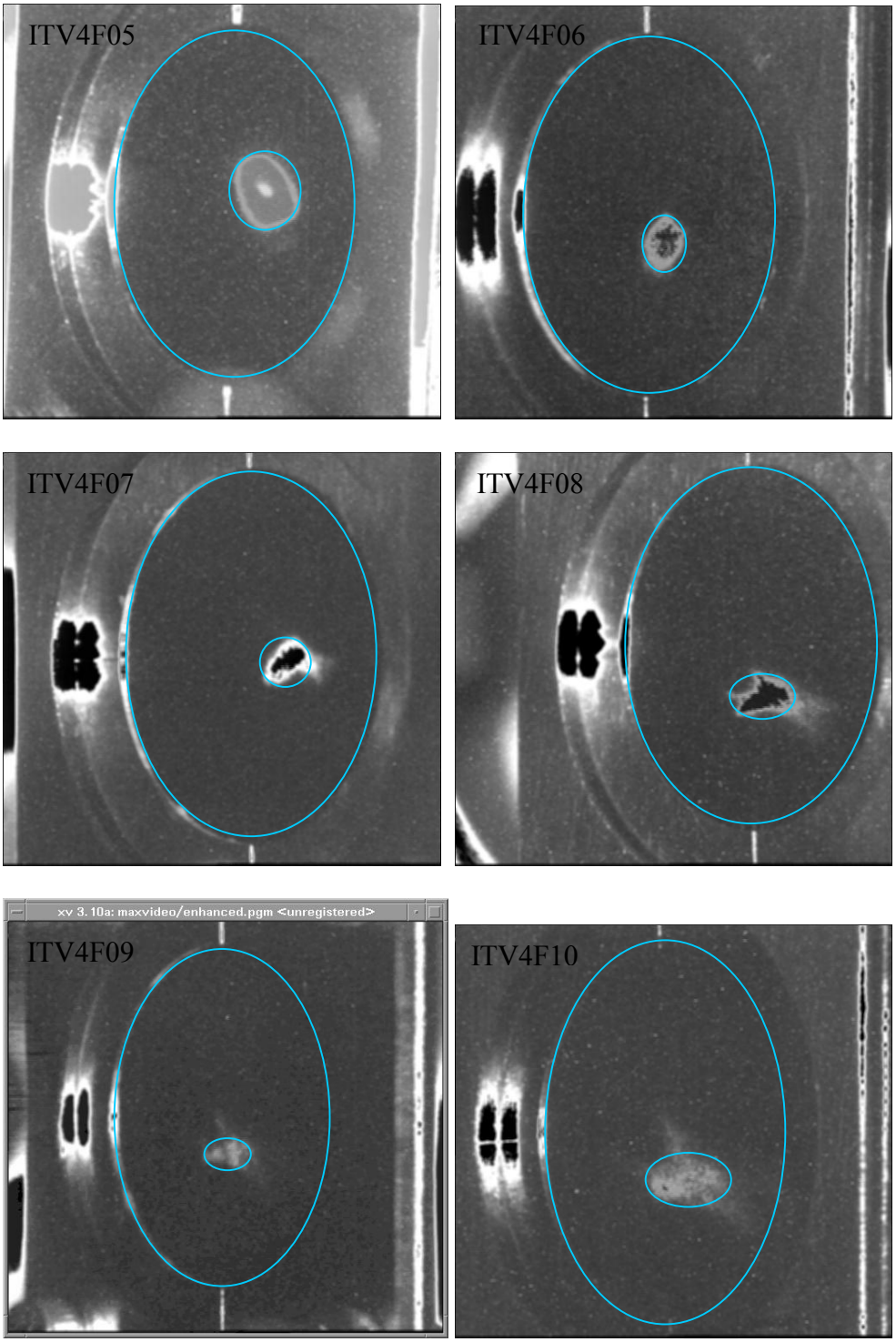
Approximate spot sizes can be obtained from the viewer images by circumscribing ellipses (here, done manually) around the beam spot images and comparing their dimensions to the image size of the 25 mm diameter viewer foil. This provides a full spot size, which we assume represents 4σ of the beam extent. Results from this comparison are given in Table 2. As the method is crude and the results therefore "ballpark" at best, we have ignored tails on and skewing of the beam while circumscribing ellipses around spot images. Details such as these can be incorporated in the measurement and data analysis when more a quantitative treatment is performed using distribution analysis features of the MaxVideo and its associated software.

Table 2: Beam Size Data From Viewer Images

Viewer	H/V frame image size (mm)	H/V spot image size (mm)	Full H spot size (mm)	Full V spot size (mm)	RMS H spot size (mm)	RMS V spot size (mm)
ITV4F05	34.9/50.4	10.4/11.4	7.4	5.7	1.8	1.4
ITV4F06	36.6/51.8	6.4/8.3	4.4	4.0	1.1	1.0
ITV4F07	36.4/53.0	7.4/7.2	5.1	3.4	1.3	0.8
ITV4F08	36.6/51.8	9.5/6.6	6.5	3.2	1.6	0.8
ITV4F09	31.3/49.0	6.8/4.7	5.4	2.4	1.4	0.6
ITV4F10	34.9/55.8	12.4/7.9	8.9	3.5	2.2	0.9

When reduced using standard methods, these data suggest geometric horizontal and vertical emittances of ε_x = 0.28 mm-mrad and ε_y = 0.085 mm-mrad, and incident beam envelope functions of β_x = 11.6 m, α_x = 0.96, β_y = 23.0 m, α_y = 1.98. When scaled by the 48 MeV electron energy, the associated normalized emittances are determined to be ε^N_x = 26 mm-mrad and ε^N_y = 8 mm-mrad. We reiterate that the spot size data on which these results are based was approximate at best; not only were they "upper limit" values, but moreover they ignore evident tails on, and skewing of, the beam. This skewing is apparent at many locations throughout the driver transport system and is probably due to uncompensated HOM-generated skew quad effects in the SRF portions of the machine. A more comprehensive treatment of this problem (based on detailed quantitative data derived from the MaxVideo display) can readily describe this effect.

Figure 1: OTR viewer images with circumscribed ellipses.



References

[1] Dunham, B., D. Douglas, R. Legg, and B. Bowling, "Analysis of Emittance Measurements Using Single and Multiple Harps", CEBAF-TN-96-014, 22 February 1996.

[2] *ibid.*

[3] Douglas, D., J. Bisognano, C. Bohn, B Bowling, B. Dunham, G. Krafft, R. Legg, and R. Li, "Measurement of CSR-Driven Emittance Growth in the Jefferson Lab IR-FEL Driver", JLAB-TN-97-018, 19 May 1997.