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INFORMAL REPORT

BROOKHAVEN ACCELERATOR TEST FACILITY
PHOTOCATHODE GUN AND TRANSPORT BEAMLINE

Z. PARSA, L. YOUNG

BNL Report

CENTER FOR ACCELERATOR PHYSICS

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.

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UNITED STATES DEPARTMENT OF ENERGY

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**BROOKHAVEN NATIONAL LABORATORY
UPTON, N.Y. 11973**

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Brookhaven Accelerator Test Facility
Photocathode Gun and Transport Beamline

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We present an analysis of the electron beam emitted from a laser driven photocathode injector (Gun, operating at 2856 MHZ), through a Transport beamline [1], to the LINAC entrance for the Brookhaven Accelerator Test Facility (ATF). The beam parameters including beam energy, and emittance are calculated. Some of our results, are tabulated and the phase plots of the beam parameters, (at downstream end of the elements), from Cathode, through the Transport line elements, to the LINAC entrance (labeled as element 27)), are shown.

Tables I-1, I-2 and Fig. 1 show the layout (including lengths and magnet strengths, in CGS units), and labeling (n) of the elements respectively. E.g., element n=1 is the cathode, specified as a zero length (dz=0) drift; n=4, is a 2.22 cm length drift (dz=2.22), from the gun exit to the 1st quadrupole in the transport beamline, etc. Where the particles are transported from the gun exit (downstream end of element ne=3) through the beamline to the LINAC entrance (element ne=27).

Table I-3 a, include the (calculated) Gun parameters (e.g. energy "w", emittance "rms" and "90%" etc.), from cathode (element labeled as ne=0) through the 1 1/2 cell cavity, (to the GUN exit, ne=3). Tables I-3 b, and I-3c, show the beam parameters calculated with space charge turned off (e.g. energy, emittance etc.), and Figures 2-3 to 2-27 (labeled by element numbers), show the phase plots of the beam at the downstream end of the elements. For example, Fig. 2-3, show a set of 4 phase plots (x vs xp, y vs yp, y vs x, and e vs phi), as well as the number of particles (ngood = 988), the energy (e=3.996 MeV), etc., that describes the beam at the downstream end of element 3.

Table II - a, b, c show the beam parameters calculated including the space charge effects, (Tables I- 3a, b, c, provided similar information without the space charge); and Figures 3-3 to 3-27, show the phase plots for the beam at downstream end of the elements

along the transport line to the LINAC entrance, (with the space charge turned on). A summary, Table and Figure captions and References are also included. We included some data in the input and output format of program PARMELA for illustration, and for your convenience in the comparison with the results obtained with various (older) versions of this program, (as was requested by some users of PARMELA). Front - End Layout of the BNL Accelerator Test Facility, showing the location and dimensions of the elements along the beamline is given on the inside back cover for convenience (as a quick reference).

Table I - 1. Layout of the elements for the ATF - Photocathode RF Gun and Transport line to the LINAC Entrance (element 27). dz is the element length, in [cm].

zout	n	z1	element	z2	dz	phase	amp
	1	0.0	drift	0.0	0.000		
	2	0.0	cell	2.6	2.625	0.000	63.750
	3	2.6	cell	7.9	5.250	-180.000	63.750
	4	7.9	drift	10.1	2.220		
	5	10.1	quad	22.2	12.065		
	6	22.2	drift	22.8	0.600		
	7	22.8	quad	43.6	20.830		
	8	43.6	drift	44.2	0.600		
	9	44.2	quad	56.3	12.065		
	10	56.3	drift	112.1	55.815		
	11	112.1	bend	132.1	20.000		
	12	132.1	drift	152.3	20.202		
	13	152.3	quad	164.3	12.065		
	14	164.3	drift	179.0	14.700		
	15	179.0	drift	193.7	14.700		
	16	193.7	quad	205.8	12.065		
	17	205.8	drift	226.0	20.202		
	18	226.0	bend	246.0	20.000		
	19	246.0	drift	273.8	27.793		
	20	273.8	quad	288.2	14.400		
	21	288.2	drift	288.8	0.600		
	22	288.8	quad	312.2	23.370		
	23	312.2	drift	312.8	0.600		
	24	312.8	quad	327.2	14.400		
	25	327.2	drift	388.4	61.240		
	26	388.4	drift	408.6	20.230		
	27	408.6	drift	439.6	30.925

Figure 1. BNL Accelerator Test Facility Injection System

Table I - 2. show the Layout of the elements for the -
Gun and Transport line (to the LINAC Entrance (element 27))
in PARMELA input format. Where the lengths and strengths
of the magnets are given.

parmela program 13:23:53.86 01/23/90
freq= 2856.00 mhz.

ATF PHOTOCATHODE RF GUN + TRANSPORT LINE Z.P.

title

input 9 999 .3 .9 2.06 6.18

drift 0 1 1

cell 2.625 1. 1 0. 63.75 1 5 -1

tape7

cfld 1

cell 5.25 1. 1 180. 63.75 1 10.

drift 2.22 5 1

quad 12.065 5.08 1 -111.36

drift .6 5 1

quad 20.83 5.08 1 72.86

drift .6 5 1

quad 12.065 5.08 1 -61.36

drift 55.815 5 1

bend 20.00 1.5 1 4.02 90 0 0 6.075 6.075

drift 20.2025 5 1

quad 12.065 3.81 1 33.58

drift 14.7 5 1

drift 14.7 5 1

quad 12.065 3.81 1 33.58

drift 20.2025 5 1

bend 20.00 1.5 1 4.02 90 0 0 6.075 6.075

drift 27.7926 5 1

quad 14.4 3.81 1 -78.36

drift .6 5 1

quad 23.37 3.81 1 61.94

drift .6 5 1

quad 14.4 3.81 1 -78.36

drift 61.24 5 1

drift 20.23 5 1

drift 30.925 5 1

Table I - 3a. Gun parameters calculated with PARMELA.
 Units of phase are in [degrr], Energy Wr in [MeV].
 The space charge effects are also included.

ne np	ref phase	zr	zr-zmin	zmax-zr	wr	wmin	wmax
01000	69.0(69.)	0.0	0.0	0.0	0.010	0.000	0.049
11000	65.2(65.)	0.0	5.1	6.2	0.000	0.000	0.000
01000	79.0(79.)	0.1	0.1	0.1	0.118	0.040	0.203
01000	89.0(89.)	0.3	0.1	0.1	0.310	0.189	0.417
01000	99.0(99.)	0.6	0.2	0.1	0.536	0.397	0.551
01000	109.0(109.)	0.9	0.2	0.1	0.764	0.621	0.880
01000	119.0(119.)	1.1	0.2	0.1	0.973	0.835	1.083
01000	129.0(129.)	1.4	0.2	0.1	1.147	1.022	1.248
01000	139.0(139.)	1.7	0.2	0.1	1.277	1.170	1.365
01000	149.0(149.)	2.0	0.2	0.1	1.360	1.272	1.436
01000	159.0(159.)	2.2	0.2	0.1	1.402	1.330	1.468
0 999	169.0(169.)	2.5	0.2	0.1	1.415	1.353	1.475
0 998	179.0(179.)	2.8	0.2	0.1	1.415	1.358	1.474
2 999	172.8(173.)	2.6	5.0	6.6	1.416	1.358	1.475
0 997	189.0(189.)	3.1	0.2	0.1	1.419	1.358	1.479
0 995	193.0(199.)	3.4	0.2	0.1	1.443	1.369	1.509
0 992	209.0(209.)	3.6	0.2	0.1	1.502	1.411	1.577
0 989	219.0(219.)	3.9	0.2	0.1	1.605	1.502	1.690
0 988	229.0(229.)	4.2	0.2	0.1	1.756	1.645	1.851
0 988	239.0(239.)	4.5	0.2	0.1	1.952	1.833	2.055
0 988	249.0(249.)	4.8	0.2	0.1	2.185	2.056	2.293
0 988	259.0(259.)	5.1	0.2	0.1	2.444	2.304	2.555
0 988	269.0(269.)	5.4	0.2	0.1	2.717	2.566	2.829
0 988	279.0(279.)	5.6	0.2	0.1	2.991	2.831	3.098
0 988	289.0(289.)	5.9	0.2	0.1	3.250	3.089	3.353
0 988	299.0(299.)	6.2	0.2	0.1	3.483	3.327	3.577
0 988	309.0(309.)	6.5	0.2	0.1	3.678	3.535	3.761
0 988	319.0(319.)	6.8	0.2	0.1	3.825	3.704	3.895
0 988	329.0(329.)	7.1	0.2	0.1	3.922	3.826	3.980
0 988	339.0(339.)	7.4	0.2	0.1	3.974	3.898	4.023
0 988	349.0(349.)	7.7	0.2	0.1	3.994	3.927	4.038
0 988	359.0(359.)	8.0	0.2	0.1	3.996	3.933	4.039
2 988	356.2(356.)	7.9	5.0	7.1	3.996	3.933	4.039
0 988	369.0(9.)	8.2	0.2	0.1	3.996	3.933	4.039
0 988	379.0(19.)	8.5	0.2	0.1	3.996	3.933	4.039
0 988	389.0(29.)	8.8	0.2	0.1	3.996	3.933	4.040

Table I - 3b. Beam parameters calculated with PARMELA, for the Transport line (element no. 4 - 27) Units of phase are in [degrr], Energy Wr in [MeV], (with the space charge turned off).

PAC

ne	np	ref phase	zr	zr-zmin	zmax-zr	wr	wmin	wmax
4	988	432.8(73.)	10.1	5.0	7.3	3.996	3.933	4.040
5	988	849.3(129.)	22.2	4.8	8.8	3.996	3.933	4.040
6	988	870.0(150.)	22.8	4.8	9.0	3.996	3.933	4.040
7	988	1589.0(149.)	43.6	4.6	12.7	3.996	3.933	4.040
8	988	1609.7(170.)	44.2	4.6	13.0	3.996	3.933	4.040
9	988	2026.2(226.)	56.3	4.5	15.7	3.996	3.933	4.040
10	988	3952.8(353.)	112.1	4.6	17.4	3.996	3.933	4.040
11	988	4641.9(322.)	132.1	9.4	44.7	3.996	3.933	4.040
12	988	5339.3(299.)	152.3	9.4	44.9	3.996	3.933	4.040
13	988	5755.7(356.)	164.3	9.4	45.0	3.996	3.933	4.040
14	988	6263.1(143.)	179.0	9.3	45.1	3.996	3.933	4.040
15	988	6770.6(291.)	193.7	9.2	45.2	3.996	3.933	4.040
16	988	7187.0(347.)	205.8	9.1	45.2	3.996	3.933	4.040
17	988	7884.4(324.)	226.0	9.1	45.1	3.996	3.933	4.040
18	949	8573.4(293.)	246.0	1.1	17.6	3.996	3.942	4.040
19	949	9532.7(173.)	273.8	1.2	18.9	3.996	3.942	4.040
20	948	10029.8(310.)	288.2	1.2	23.4	3.996	3.942	4.040
21	948	10050.5(331.)	288.8	1.2	24.0	3.996	3.942	4.040
22	934	10857.3(57.)	312.2	1.3	24.5	3.996	3.942	4.040
23	934	10878.0(78.)	312.8	1.3	24.8	3.996	3.942	4.040
24	934	11375.0(215.)	327.2	1.4	27.7	3.996	3.942	4.040
25	934	13489.0(169.)	388.4	1.7	27.8	3.996	3.942	4.040
26	934	14187.3(147.)	408.6	1.8	27.9	3.996	3.942	4.040
27	934	15254.8(135.)	439.6	1.9	28.0	3.996	3.942	4.040

fraction lost in element 2=0.00100 average energy= 1.44974 MeV,

fraction lost in element 3=0.01100 average energy= 1.49823 MeV,

fraction lost in element 18=0.03900 average energy= 4.01983 MeV,

fraction lost in element 20=0.00100 average energy= 3.99214 MeV,

fraction lost in element 22=0.01400 average energy= 3.99097 MeV,

fraction good at end of calculation=0.93400 average energy= 3.99902 MeV, beam

total beam power= 11.35321 MWatt

elapased time= 1067.47secs, fraction in scheff 0.51

elapased time= 1067.47secs, fraction in scheff 0.51

Table I - 3c. Gun parameters calculated with PARMELA. Where the space charge effects are included in the calculations of the Gun parameters (element no. 1, 2, 3), but is turned off in the Transport line (elements no. 4 - 27). Units of phase are in [deg/rad], Energy W_r in [MeV] and Emittance is given in π -cm-mrad

ATF PHOTOCATHODE RF GUN + TRANSPORT LINE Z.P.

nel no.	part in	part out	rms,n x	emax,n x,90%	emax,n x,100%	rms,n y	emax,n y,90%	emax,n y,100%
1	1000	1000	0.0132	0.0988	0.8035	0.0185	0.0921	0.6516
2	1000	999	0.9543	3.9990	26.6602	0.9935	4.1602	35.9199
3	1000	988	<u>1.2067</u>	5.1348	26.1318	<u>1.2300</u>	5.1948	57.1367
4	1000	988	1.2446	5.2598	28.4180	1.2745	5.3789	61.6016
5	1000	988	3.4725	14.1250	201.2500	1.4883	6.2258	75.6992
6	1000	988	3.5598	14.8750	200.3750	1.4918	6.2402	76.2852
7	1000	988	7.1480	26.8203	344.1875	1.3553	5.5645	73.4980
8	1000	988	7.1894	27.0156	344.1562	1.3628	5.5889	74.2891
9	1000	988	5.7934	25.6169	201.7187	1.5120	6.4019	84.4556
10	1000	988	6.1091	27.6493	200.9840	1.5618	6.5975	90.9140
11	1000	988	10.7122	49.8750	311.3546	1.8197	7.4761	121.4859
12	1000	988	10.7047	49.7177	309.4838	1.8222	7.4899	122.1846
13	1000	988	10.7050	49.7080	309.1510	1.8217	7.4849	121.9353
14	1000	988	10.7101	49.7942	310.1503	1.8206	7.4808	120.8705
15	1000	983	10.7151	49.8803	311.1507	1.8195	7.4801	119.8116
16	1000	988	10.7137	49.9063	310.5264	1.8201	7.5142	116.6748
17	1000	988	10.6987	49.8165	306.8937	1.8247	7.5996	102.7139
18	1000	949	6.4219	29.1643	203.6637	3.7595	16.0112	357.6445
19	1000	949	6.4449	29.1093	203.4072	3.8590	16.6719	318.8711
20	1000	948	6.3899	29.5938	190.0000	4.1987	18.7500	82.5117
21	1000	948	6.3952	29.4583	191.0938	4.2384	18.7656	82.1543
22	1000	934	5.9303	27.2109	210.2031	5.3904	25.4717	56.0928
23	1000	934	5.9336	27.2461	211.4375	5.4313	25.6670	54.7168
24	1000	934	5.7361	27.1116	151.8080	5.8265	27.7560	58.5775
25	1000	934	5.7269	27.0847	151.7301	5.8260	27.7585	58.5507
26	1000	934	5.7239	27.0757	151.7060	5.8258	27.7593	58.5418
27	1000	934	5.7194	27.0620	151.6705	5.8255	27.7606	58.5283

subnum 7

output 2 1 1 60

optcon 1 1 2 10 1 5 0 400 0 1

begin

ATF PHOTOCATHODE RF GUN + TRANSPORT LINE Z.P.

nel	part	part	z-emittance (deg-kev)			dpb	dwb	alpha	beta
	in	out	rms	90%	100%				
1	1000	1000	0.000	0.000	0.010	0.00	0.00	0.173	*****

Table II - a. Gun parameters calculated with PARMELA.
 Units of phase are in [degrr], Energy W_r in [MeV].
 (The space charge effects are also included.).

ne	ng	ref phase	zr	zr-zmin	zmax-zr	wr	wmin	wmax
01000	69.0(69.)	0.0	0.0	0.0	0.010	0.000	0.048	
11000	65.2(65.)	0.0	5.1	6.3	0.000	0.000	0.000	
01000	79.0(79.)	0.1	0.1	0.1	0.118	0.039	0.201	
01000	89.0(89.)	0.3	0.1	0.1	0.310	0.188	0.414	
01000	99.0(99.)	0.6	0.2	0.1	0.536	0.398	0.647	
01000	109.0(109.)	0.8	0.2	0.1	0.764	0.623	0.875	
01000	119.0(119.)	1.1	0.2	0.1	0.973	0.836	1.079	
01000	129.0(129.)	1.4	0.2	0.1	1.148	1.021	1.244	
01000	139.0(139.)	1.7	0.2	0.1	1.277	1.165	1.362	
01000	149.0(149.)	2.0	0.2	0.1	1.360	1.263	1.434	
01000	159.0(159.)	2.2	0.2	0.1	1.402	1.317	1.466	
0 997	169.0(169.)	2.5	0.2	0.1	1.415	1.339	1.474	
0 996	179.0(179.)	2.8	0.2	0.1	1.416	1.343	1.472	
2 996	172.8(173.)	2.6	4.9	6.3	1.416	1.343	1.474	
0 993	189.0(189.)	3.1	0.2	0.1	1.419	1.344	1.478	
0 990	199.0(199.)	3.4	0.2	0.1	1.443	1.360	1.507	
0 989	209.0(209.)	3.6	0.2	0.1	1.502	1.406	1.574	
0 987	219.0(219.)	3.9	0.2	0.1	1.605	1.495	1.688	
0 985	229.0(229.)	4.2	0.2	0.1	1.756	1.633	1.849	
0 985	239.0(239.)	4.5	0.2	0.1	1.952	1.817	2.052	
0 985	249.0(249.)	4.8	0.2	0.1	2.186	2.041	2.290	
0 985	259.0(259.)	5.1	0.2	0.1	2.445	2.295	2.550	
0 985	269.0(269.)	5.4	0.2	0.1	2.718	2.565	2.822	
0 985	279.0(279.)	5.6	0.2	0.1	2.991	2.838	3.092	
0 985	289.0(289.)	5.9	0.2	0.1	3.251	3.102	3.346	
0 985	299.0(299.)	6.2	0.2	0.1	3.484	3.343	3.571	
0 985	309.0(309.)	6.5	0.2	0.1	3.678	3.550	3.756	
0 985	319.0(319.)	6.8	0.2	0.1	3.825	3.712	3.891	
0 985	329.0(329.)	7.1	0.2	0.1	3.923	3.826	3.979	
0 985	339.0(339.)	7.4	0.2	0.1	3.975	3.892	4.023	
0 985	349.0(349.)	7.7	0.2	0.1	3.994	3.920	4.037	
0 985	359.0(359.)	8.0	0.2	0.1	3.996	3.926	4.039	
3 985	356.2(356.)	7.9	4.8	6.5	3.996	3.926	4.039	
0 985	369.0(9.)	8.2	0.2	0.1	3.996	3.926	4.039	
0 985	379.0(19.)	8.5	0.2	0.1	3.996	3.926	4.039	
0 985	389.0(29.)	8.8	0.2	0.1	3.996	3.926	4.040	

Table II - c. Beam parameters calculated with PARMELA. Where the space charge effects are included in the calculations of the Gun parameters (element no. 1, 2, 3), as well as in the Transport line (elements no. 4 - 27). Units of phase are in [degrr], Energy W_r in [MeV] and Emittance is given in $\mu\text{m-rad}$.

ATF PHOTOCATHODE RF GUN + TRANSPORT LINE Z.P.

nel no.	part in	part out	rms,n x	emax,n x,90%	emax,n x,100%	rms,n y	emax,n y,90%	emax,n y,100%
1	1000	1000	0.0179	0.0905	0.5604	0.0179	0.0830	0.8838
2	1000	996	0.8131	3.4924	24.0690	0.8278	3.4648	33.6758
3	1000	985	1.0407	4.5635	26.1309	1.0251	4.3701	29.0820
4	1000	985	1.0943	4.8916	28.0020	1.0778	4.6367	30.7148
5	1000	985	3.3261	14.8750	199.3750	1.4276	6.1252	41.2148 -
6	1000	985	3.4560	15.6875	192.5000	1.4359	6.1582	41.4707 -
7	1000	985	7.2952	29.3201	410.7500	1.4120	6.1123	39.2656
8	1000	985	7.3751	29.7773	409.0625	1.4256	6.2227	39.4375
9	1000	985	6.7847	31.1572	230.7900	1.6891	7.4645	46.3711
10	1000	985	7.8534	36.9759	240.8664	2.3488	9.9772	63.9683
11	1000	985	19.2248	87.7093	420.9501	2.9970	12.5676	94.8413
12	1000	985	19.3901	88.3686	419.7580	3.1094	13.1872	96.9594
13	1000	985	19.4225	88.5730	416.9652	3.1406	13.3419	96.8334
14	1000	985	19.4471	88.7946	413.5914	3.1915	13.7032	95.5842
15	1000	985	19.4327	88.7930	409.9117	3.2394	13.9891	94.0471
16	1000	985	19.4061	88.8292	407.4031	3.3763	14.7773	89.6773
17	1000	985	19.3045	88.8448	404.8661	3.9370	17.9258	75.4239
18	1000	551	15.5450	64.9597	329.6245	4.1976	20.5479	86.9629
19	1000	551	15.4496	65.3918	326.3318	4.8109	25.1211	79.6055
20	1000	551	15.6631	65.4531	473.8594	6.6698	33.9766	108.5625
21	1000	551	15.6470	65.3203	472.2344	6.9088	34.9219	114.9687
22	1000	545	14.1872	62.1602	168.6875	12.9166	67.6108	244.0098
23	1000	545	14.1911	62.2734	169.6953	13.0776	68.3701	246.6079
24	1000	545	14.0735	60.5636	157.4741	14.5596	74.5147	269.6555
25	1000	545	14.0955	60.9868	159.1629	14.2782	74.1068	265.7955
26	1000	545	14.1257	61.1773	159.1187	14.1915	73.1453	264.0403
27	1000	545	14.1641	61.2209	157.9046	14.1000	72.3882	261.5128

subnum 7

Following Figures (2 - 3 to 2 - 27), show phase plots of the beam parameters, along the ATF Transport beamline. The plots show the beam profiles at downstream ends of the elements, (with space charge turned "off" in the beamline):

Fig. 2 - 3. Beam profiles at the Gun exit. This plot shows the parameters obtained at the downstream end of element 3 (which is the start of the Transport line).

Figure 2-5. Shows phase plots of the beam parameters, at the downstream end of element 5 (1st quadrupole)

Figure 2-7. Shows phase plots of the beam parameters, at the downstream end of element 7 (2nd quadrupole)

Figure 2-9. Shows phase plots of the beam parameters, at the downstream end of element 9 (3rd quadrupole)

Figure 2-10. Shows phase plots of the beam parameters, at the downstream end of element 10 (end of the drift at the entrance to the 1st dipole in the beamline).

Figure 2-11. Shows phase plots of the beam parameters, at the downstream end of element 11 (the 1st dipole).

Figure 2-12. Shows phase plots of the beam parameters, at the downstream end of element 12 (end of the drift at the entrance to the 4th quadrupole in the beamline).

Figure 2-13. Shows phase plots of the beam parameters, at the downstream end of element 13 (4th quadrupole).

Figure 2-14. Shows phase plots of the beam parameters, at the downstream end of element 14 (end of the drift at the momentum slit (see Fig. 1)).

Figure 2-16. Shows phase plots of the beam parameters, at the downstream end of element 16 (5th quadrupole)

Figure 2-17. Shows phase plots of the beam parameters, at the downstream end of element 17 (end of the drift at the entrance to the 2nd dipole in the beamline).

Figure 2-18. Shows phase plots of the beam parameters, at the downstream end of element 18 (the 2nd dipole).

Figure 2-19. Shows phase plots of the beam parameters, at the downstream end of element 19 (end of the drift at the entrance to the 6th quadrupole in the beamline).

Figure 2-20. Shows phase plots of the beam parameters,

at the downstream end of element 20 (the 6th quadrupole in the beamline).

Figure 2-22. Shows phase plots of the beam parameters, at the downstream end of element 22 (the 7th quadrupole in the beamline).

Figure 2-24. Shows phase plots of the beam parameters, at the downstream end of element 24 (the 8th quadrupole in the beamline)

Figure 2-27. Shows phase plots of the beam parameters, at the downstream end of element 27 (end of the last drift in the beamline), i.e. entrance to the LINAC.

Fig. 2 - 3. Beam profiles at the Gun exit. This plot shows the parameters obtained at the downstream end of element 3 (which is the start of the Transport line).

Figure 2-5. Shows phase plots of the beam parameters, at the downstream end of element 5 (1st quadrupole)

Figure 2-7. Shows phase plots of the beam parameters, at the downstream end of element 7 (2nd quadrupole)

Figure 2-9. Shows phase plots of the beam parameters, at the downstream end of element 9 (3rd quadrupole)

Figure 2-10. Shows phase plots of the beam parameters, at the downstream end of element 10 (end of the drift at the entrance to the 10 dipole in the beamline).

Figure 2-11. Shows phase plots of the beam parameters, at the downstream end of element 11 (the 1st dipole).

Figure 2-12. Shows phase plots of the beam parameters, at the downstream end of element 12 (end of the drift at the entrance to the 4th quadrupole in the beamline).

Figure 2-13. Shows phase plots of the beam parameters, at the downstream end of element 13 (4th quadrupole)

Figure 2-14. Shows phase plots of the beam parameters, at the downstream end of element 14 (end of the drift at the momentum slit (see Fig. 1)).

Figure 2-16. Shows phase plots of the beam parameters, at the downstream end of element 16 (5th quadrupole)

Figure 2-17. Shows phase plots of the beam parameters, at the downstream end of element 17 (end of the drift at the entrance to the 2nd dipole in the beamline).

Figure 2-18. Shows phase plots of the beam parameters, at the downstream end of element 18 (the 2nd dipole).

Figure 2-19. Shows phase plots of the beam parameters, at the downstream end of element 19 (end of the drift at the entrance to the 6th quadrupole in the beamline).

Figure 2-20. Shows phase plots of the beam parameters, at the downstream end of element 20 (the 6th quadrupole in the beamline).

Figure 2-22. Shows phase plots of the beam parameters. at the downstream end of element 22 (the 7th quadrupole in the beamline).

Figure 2-24. Shows phase plots of the beam parameters, at the downstream end of element 24 (the 8th quadrupole in the beamline)

Figure 3-11. Shows phase plots of the beam parameters, at the downstream end of element 11 (the 1st dipole).

Figure 3-12. Shows phase plots of the beam parameters, at the downstream end of element 12 (end of the drift at the entrance to the 4th quadrupole in the beamline).

Figure 3-14. Shows phase plots of the beam parameters, at the downstream end of element 14 (end of the drift at the momentum slit (see Fig. 1)).

Figure 3-16. Shows phase plots of the beam parameters, at the downstream end of element 16 (5th quadrupole)

Figure 3-17. Shows phase plots of the beam parameters, at the downstream end of element 17 (end of the drift at the entrance to the 2nd dipole in the beamline).

Figure 3-18. Shows phase plots of the beam parameters, at the downstream end of element 18 (the 2nd dipole).

Figure 3-19. Shows phase plots of the beam parameters, at the downstream end of element 19 (end of the drift at the entrance to the 6th quadrupole in the beamline).

Figure 3-20. Shows phase plots of the beam parameters, at the downstream end of element 20 (the 6th quadrupole in the beamline).

Figure 3-22. Shows phase plots of the beam parameters, at the downstream end of element 22 (the 7th quadrupole in the beamline).

Figure 3-24. Shows phase plots of the beam parameters, at the downstream end of element 24 (the 8th quadrupole in the beamline)

Figure 3-27. Shows phase plots of the beam parameters, at the downstream end of element 27 (end of the last drift in the beamline), i.e. entrance to the LINAC.

Summary:

We have studied the BNL ATF Photocathode and transport beamline, with PARMELA [2], (the standard design program at ATF), and found differences in the results obtained for the Gun output parameters (e.g., Table I-3c shows the the emittance of ~ 12 pi-mm=mrاد) as compared with the earlier calculations (of ~ 7.3 pi-mm=mrاد, [1]).

As can be seen from the tables and phase plots the beam emittance, (e.g., Table II-c shows that the rms emittance $\{x, y\}$, in pi-cm=mrاد), grows from $\{1.0407, 1.025\}$, at the Gun exit with 988 particles, (to $\{19.45, 3.19\}$ at the location of the momentum slit, and), to $\{14.16, 14.1\}$, at the LINAC entrance where 545 particles survived, (more than a 10% increase in the beam emittance!).

Our results with PARMELA, for the beamline, confirms our earlier findings with Lie Algebraic method [3], that showed increases in the beamsize, emittance, etc. Our analysis indicated that the beam is diverging too much, the beam get too big, leading to large beam emittance growth [also discussed in Ref 4,6]. We have recommended [6], some possible solutions; e.g. by an overall improvement in the Gun performance and placing of the Gun directly to the LINAC entrance, thus avoiding the transport beamline completely; by a better fitting, (e.g. changing the quadrupole strengths, etc.), by including the nonlinear terms in the calculations; or by using slits (see earlier work e.g. Ref. [5]), to reduce the beam size. For

Additional results of our analysis for the ATF Photocathode Gun see e.g. Refs. [6].

The analysis was made by inputting the field we obtained via program SUPERFISH, into program PARMELA, and calculating the transverse and longitudinal beam parameters at various points from cathode through the transport line to the LINAC entrance, including the beam energy and emittance at various points.

Different versions of program PARMELA, have been used in last few years for the Design and Analysis of the BNL photocathode Gun at ATF (Accelerator Test Facility), that have resulted in variations in the output parameters calculated for the same Gun (e.g by McDonald, Pellegrini, Kirk, Gallardo, Juang, and others, received privately and or presented at ATF meetings, through 1/1990). To clarify some of the differences in the results obtained by these individuals with various versions of PARMELA, we have used the Gun design parameters (from blue print no. SLS-41.24-1-4-A, (received from K. Batchelor, BNL NSLS), as our input and evaluated the output parameters of the "Gun" via program PARMELA (in collaboration with the author of PARMELA), (see REF [6], for more info. on our results for the ATF - Photocathode Gun).

The initial parameters used were, the frequency $f=2856$ MHz, beam size of $r = 0.3$ cm and $z = 2.06$ degrees (where 2 ps = 2.06 degrees), that would result in the proposed beam, with momentum of ~ 4.5 MeV/c at the Gun exit, (i.e. the entrance to the Transport line), from which point the beam parameters were

calculated through the ATF Transport beamline (to the LINAC Entrance), with the space charge turned "on" (1 nC), and "off", (see phase plots in Figs 2 and 3, respectively).

Table Captions:

Table I - 1. Layout of the elements for the ATF - Photocathode RF Gun and Transport line to the LINAC Entrance (element 27). dz is the element length, in [cm].

Table I - 2. show the Layout of the elements for the - Gun and Transport line (to the LINAC Entrance (element 27)) in PARMELA input format. Where the lengths and strengths of the magnets are given.

Table I - 3a. Gun parameters calculated with PARMELA. Units of phase are in [degree], Energy W_r in [MeV]. The space charge effects are also included.

Table I - 3b. Beam parameters calculated with PARMELA, for the Transport line (element no. 4 - 27) Units of phase are in [degree], Energy W_r in [MeV], (with the space charge turned off).

Table I - 3c. Gun parameters calculated with PARMELA. Where the space charge effects are included in the calculations of the Gun parameters (element no. 1, 2, 3), but is turned off in the Transport line (elements no. 4 - 27). Units of phase are in [degree], Energy W_r in [MeV] and Emittance is given in pi-cm-mrad.

Table II - a. Gun parameters calculated with PARMELA. Units of phase are in [degree], Energy W_r in [MeV]. (The space charge effects are also included.).

Table II - b. Beam parameters calculated with PARMELA. for the Transport line, (element 4 - 27). Units of phase are in [degree], Energy W_r in [MeV], (with the space charge turned on in the beamline).

Table II - c. Beam parameters calculated with PARMELA. Where the space charge effects are included in the calculations of the Gun parameters (element no. 1, 2, 3), as well as in the Transport line (elements no. 4 - 27). Units of phase are in [degree], Energy W_r in [MeV] and Emittance is given in pi-cm-mrad.

Figure Captions

Figure 1, Schematic Layout of the ATF Injection System

FIGURES 2 - 3 TO 2 - 27 , SHOW PHASE PLOTS OF THE BEAM PARAMETERS, ALONG THE atf TRANSPORT BEAMLINE. THE PLOTS SHOW THE BEAM PROFILES AT DOWNSTREAM ENDS OF THE ELEMENTS, (WITH SPACE CHARGE TURNED "OFF" IN THE BEAMLINE):

Fig. 2 - 3. Beam profiles at the Gun exit. This plot shows the parameters obtained at the downstream end of element 3 (which is the start of the Transport line).

Figure 2-5. Shows phase plots of the beam parameters, at the downstream end of element 5 (1st quadrupole)

Figure 2-7. Shows phase plots of the beam parameters, at the downstream end of element 7 (2nd quadrupole)

Figure 2-9. Shows phase plots of the beam parameters, at the downstream end of element 9 (3rd quadrupole)

Figure 2-10. Shows phase plots of the beam parameters, at the downstream end of element 10 (end of the drift at the entrance to the 1st dipole in the beamline).

Figure 2-11. Shows phase plots of the beam parameters, at the downstream end of element 11 (the 1st dipole).

Figure 2-12. Shows phase plots of the beam parameters, at the downstream end of element 12 (end of the drift at the entrance to the 4th quadrupole in the beamline).

Figure 2-13. Shows phase plots of the beam parameters, at the downstream end of element 13 (4th quadrupole)

Figure 2-14. Shows phase plots of the beam parameters, at the downstream end of element 14 (end of the drift at the momentum slit (see Fig. 1)).

Figure 2-16. Shows phase plots of the beam parameters, at the downstream end of element 16 (5th quadrupole)

Figure 2-17. Shows phase plots of the beam parameters, at the downstream end of element 17 (end of the drift at the entrance to the 2nd dipole in the beamline).

Figure 2-18. Shows phase plots of the beam parameters, at the downstream end of element 18 (the 2nd dipole).

Figure 2-19. Shows phase plots of the beam parameters,

at the downstream end of element 19 (end of the drift at the entrance to the 6th quadrupole in the beamline).

Figure 2-20. Shows phase plots of the beam parameters, at the downstream end of element 20 (the 6th quadrupole in the beamline).

Figure 2-22. Shows phase plots of the beam parameters, at the downstream end of element 22 (the 7th quadrupole in the beamline).

Figure 2-24. Shows phase plots of the beam parameters, at the downstream end of element 24 (the 8th quadrupole in the beamline)

Figure 2-27. Shows phase plots of the beam parameters, at the downstream end of element 27 (end of the last drift in the beamline), i.e. entrance to the LINAC.

FIGURES 3 - 3 TO 3 - 27, SHOW PHASE PLOTS OF THE BEAM PARAMETERS, ALONG THE TRANSPORT BEAMLINE. THE PLOTS SHOW THE BEAM PROFILES AT DOWNSTREAM ENDS OF THE ELEMENTS, (WITH SPACE CHARGE TURNED "ON" IN THE BEAMLINE):

Fig. 3- 3. Beam profiles at the Gun exit. This plot shows the parameters obtained at the downstream end of element 3 (which is the start of the Transport line).

Figure 3-5. Shows phase plots of the beam parameters, at the downstream end of element 5 (1st quadrupole)

Figure 3-7. Shows phase plots of the beam parameters, at the downstream end of element 7 (2nd quadrupole)

Figure 3-9. Shows phase plots of the beam parameters, at the downstream end of element 9 (3rd quadrupole)

Figure 3-10. Shows phase plots of the beam parameters, at the downstream end of element 10 (end of the drift at the entrance to the 1st dipole in the beamline).

Figure 3-11. Shows phase plots of the beam parameters, at the downstream end of element 11 (the 1st dipole).

Figure 3-12. Shows phase plots of the beam parameters, at the downstream end of element 12 (end of the drift at the entrance to the 4th quadrupole in the beamline).

Figure 3-13. Shows phase plots of the beam parameters, at the downstream end of element 13 (4th quadrupole)

Figure 3-14. Shows phase plots of the beam parameters, at the downstream end of element 14 (end of the drift at the momentum slit (see Fig. 1)).

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Figure 3-19. Shows phase plots of the beam parameters, at the downstream end of element 19 (end of the drift at the entrance to the 6th quadrupole in the beamline).

Figure 3-20. Shows phase plots of the beam parameters, at the downstream end of element 20 (the 6th quadrupole in the beamline).

Figure 3-22. Shows phase plots of the beam parameters, at the downstream end of element 22 (the 7th quadrupole in the beamline).

Figure 3-24. Shows phase plots of the beam parameters, at the downstream end of element 24 (the 8th quadrupole in the beamline)

Figure 3-27. Shows phase plots of the beam parameters, at the downstream end of element 27 (end of the last drift in the beamline), i.e. entrance to the LINAC.

References:

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- [1] Presentations, by K. Batchelor et al, e.g. BNL Report BNL- 43702; Proceedings of Acc. Physics Conf., Williamsburg, Va, (1988), AIP Part. Acc. Conf., Chicago, Ill. (1989).
 - [2] L. Young, program PARMELA, LANL, Los Alamos, New Mexico, (1990).
 - [3] Z. Parsa, Emittance Analysis with Linear and Non - Linear aberrations for ATF Transport Beamline, ADD/CAP/TN 17, (10/16/89); ADD/CAP/TN 19, (11/9/89), with program MARYLIE and TRANSPORT.
 - [4] Z. Parsa, Emittance and Moments in Accelerators, and Beamlines (I), CAP Note 2 (10/16/90); and Proceedings of CAP BNL-Report (1990).
ibid, Emittance Analysis for ATF TRANSPORT Beamline (II), CAP Note 3 (10/16/90); and Proceedings of CAP BNL-Report (1990).
 - [5] E.g., see, Z. Parsa, C. Pellegrini, Analysis of the variations in the Emittance and Beamsizes for the Transport beamline [slit = 1.5, 1.6, 1.7 mm**2], (1989).

- [6] Z. Parsa, L. Young, High Brightness Photocathode Injector for BNL Accelerator Facility, BNL-Report (1990).

Z. Parsa, On Re-evaluation of ATF - Photocathode rf Gun and the Transport Beamline, CAP Note 8 (2/13/90) and Proceeds. of CAP Meetings, BNL-Report (1990).

- [7] SUPERFISH Ref. Manual La-ur-87-126 LANL (1987). Field calculations were made with version of program SUPERFISH at LANL, (1/ 1990);

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Figure 2-27. Shows phase plots of the beam parameters, at the downstream end of element 27 (end of the last drift in the beamline), i.e. entrance to the LINAC.

Following Figures (3 - 3 to 3 - 27), show phase plots of the beam parameters, along the ATF Transport beamline. The plots show the beam profiles at downstream ends of the elements, (with space charge turned "on" in the beamline):

Fig. 3- 3. Beam profiles at the Gun exit. This plot shows the parameters obtained at the downstream end of element 3 (which is the start of the Transport line).

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Figure 3-9. Shows phase plots of the beam parameters, at the downstream end of element 9 (3rd quadrupole)

Figure 3-10. Shows phase plots of the beam parameters, at the downstream end of element 10 (end of the drift at the entrance to the 1st dipole in the beamline).

Figure 3-11. Shows phase plots of the beam parameters, at the downstream end of element 11 (the 1st dipole).

Figure 3-12. Shows phase plots of the beam parameters, at the downstream end of element 12 (end of the drift at the entrance to the 4th quadrupole in the beamline).

Figure 3-13. Shows phase plots of the beam parameters, at the downstream end of element 13 (4th quadrupole)

Figure 3-14. Shows phase plots of the beam parameters, at the downstream end of element 14 (end of the drift at the momentum slit (see Fig. 1)).

Figure 3-16. Shows phase plots of the beam parameters, at the downstream end of element 16 (5th quadrupole)

Figure 3-17. Shows phase plots of the beam parameters, at the downstream end of element 17 (end of the drift at the entrance to the 2nd dipole in the beamline).

Figure 3-18. Shows phase plots of the beam parameters, at the downstream end of element 18 (the 2nd dipole).

Figure 3-19. Shows phase plots of the beam parameters, at the downstream end of element 19 (end of the drift at the entrance to the 6th quadrupole in the beamline).

Figure 3-20. Shows phase plots of the beam parameters, at the downstream end of element 20 (the 6th quadrupole)

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Figure 3-22. Shows phase plots of the beam parameters, at the downstream end of element 22 (the 7th quadrupole in the beamline).

Figure 3-24. Shows phase plots of the beam parameters, at the downstream end of element 24 (the 8th quadrupole in the beamline)

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Figure 3-10. Shows phase plots of the beam parameters, at the downstream end of element 10 (end of the drift at the entrance to the 1st dipole in the beamline).