TO DESIGN D-LINAC FOR FUSION MATERIALS IRRADIATION FACILITY

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Abstract

We have come to conclusion that we can exceed the main characters of FMIT, IFMIF, and ESNIT.

At this moment we should like to draw your attention to the following:

1 We are able to design all accelerating structures of 35 MeV CW Deuterium BWLAP Accelerator using about 1GHz RF supply only (however, see item 6).

2 We are able to design all focusing systems of 35 MeV CW Deuterium Accelerator using Superconducting Solenoids.

3 We are able to solve the main heat transfer aspect of the accelerating structures proposed for 35 MeV CW Deuterium Accelerator.

4 We discuss the RF-supply problem.

5 We orient ourselves towards using High Voltage injection at this step. The description of usage in a few High Voltage variants are presented.

6 The alternative option to decrease the injection energy to 135 kV level by using two multiple (66 and 33 cm) waves BWLAP is discussed.

Introdution

At this moment we should like to discuss the first computer modelling results of several options D-linac for the Fusion Materials Irradiation Facility. The results were obtained being guided by the electro-dynamics data of the new BW-type accelerating structures, investigated at the "Phystech Instrument", and the experimental data of the heat and hydrolics tests of some of these structures at Design Company - KB Salyut (Moscow).

We have discussed the RF-supply problem with the authorities of the Russian High Power Electronics Industry and they have assured us that the required parameters of RF-sources have been already designed, tested, and might be used in our project.

They offer to use two options: a. a set of 0.3 MW CW magnetrons (available today, but with hope that the developing a power of a single valve up to 1 MW-level will be reached tomorrow), and b. a high average (1 MW) power and high peak (30 - 100 MW) power pulsed magnetron or a compact multibeam klystron in the near future.

To vary an accelerated particle energy we propose to use sweeping RF frequency (the results of the preliminary investigation of this approach are shown in Table 7). project. 30-100 MW) power.

We orient ourselves at using High Voltage injection (of the Oscar Anderson type: CCVV-LBL) at this step. Four High Voltage variants have just developed, and they are given in the 1 - 4 tables below.

The main results of BWLAP TW approach, in which the RF- flux is directed against the accelerated particles, to design D-linac are tabulated and shown below.

TABLE 1

1-section CW D - accelerator

λ=33cm; e/m=0.5; t=300K; k_{cap} =94.4(4)%; J=755.5mA; η=89.66%;
P =30.31; J =0.8A; B <=15.0T; E =12.0kV/cm; P =4.0MW;
R =3.772mm (in B=7.22T); dia.SCS=150mm; P_{RF} =37.1MW;

N	Q	E	W	P_i	L	ϕ_s	L_i	B
1	179	12.00	.9625	-	.4569	π/2	0	7.22
31	178	36.49	.9625	4.004	.5880	1.376	.131	12.96
116	171	45.97	1.404	4.483	.9938	1.238	.537	14.57
173	170	52.12	2.008	5.047	1.323	1.140	.866	14.38
230	170	56.19	3.015	5.876	1.722	1.035	1.265	14.70
299	170	60.97	5.034	7.534	2.330	.9013	1.873	14.74
344	170	64.28	7.032	9.165	2.820	.8129	2.363	14.60
393	170	68.59	10.06	11.64	3.453	.7190	2.996	14.31
440	170	73.16	14.03	14.91	4.174	.6348	3.717	14.10
493	170	79.48	20.12	19.97	5.139	.5509	4.682	13.70
555	170	88.09	30.04	28.36	6.502	.4722	6.045	14.65
602	170	95.83	40.12	37.04	7.723	.4276	7.266	14 68

TABLE 2

1-section CW D - accelerator

λ=33cm; e/m=0.5; t=20K; k_{cap} =94.4(4)%; J=755.5mA; η=96.80%;
P =30.39; J =0.8A; B <=15.0T; E =12.0kV/cm; P =4.0MW;
R =3.681mm (in B=7.20T); dia.SCS=160mm; P_{RF} =34.65MW;

N	Q	E	W	P_i	L	ϕ_s	L_i	B
1	179	12.00	.9625	-	.4569	π/2	0	7.22
31	178	36.49	.9625	4.004	.5880	1.376	.131	12.96
116	174	45.42	1.401	4.381	.9936	1.238	.537	14.57
174	171	51.30	2.008	4.870	1.328	1.138	.871	14.34
232	170	55.16	3.019	5.662	1.734	1.032	1.277	14.68
301	170	59.65	5.003	7.201	2.342	.8990	1.885	14.71
347	170	62.84	7.001	8.749	2.841	.8074	2.383	14.52
397	170	67.00	10.02	11.09	3.486	.7146	3.028	14.31
499	170	77.33	20.05	18.87	5.203	.5463	4.746	14.20
563	170	85.43	30.02	26.65	6.608	.4667	6.151	14.60
612	170	92.66	40.22	34.64	7.882	.4230	7.425	14 70

TABLE 3

1-section CW D - accelerator

λ=33cm; e/m=0.5; t=300K; k_{cap} =89.28%; J=250.0mA; η=86.67%;
P =9.215MW; J =0.280A; B =9.30T; E =4.0kV/cm; P =0.6MW;
R =1.854mm (in B=4.33T); dia.SCS=165mm; P_{RF} =12.0MW;

$CELL_i$	E[MV/m]	W[MeV]	P_i[MW]	Z_i[m]	ϕ_s[rad]	L_i[mm]	B[T]
1	.4000	.796	.594	.258	1.5708		4.329
202	1.5868	1.048	.717	1.097	1.200		8.537
327	1.9904	1.552	.878	1.729	1.032		9.010
398	2.2149	2.050	1.023	2.155	.9373		8.833
452	2.3843	2.574	1.171	2.523	.8663		9.019
477	the end of particle losses						
502	2.5708	3.208	1.348	2.904	.8019		8.608
522	2.6364	3.560	1.432	3.069	.7765		8.996
601	2.9449	5.006	1.850	3.787	.6817	10.059	8.900
675	3.2365	7.001	2.403	4.597	.5998	11.896	8.920
755	3.6300	10.008	3.234	5.637	.5696	14.1948	9.028
852	4.1837	15.028	4.641	7.163	.5696	17.3598	9.023
924	4.6573	20.020	6.052	8.505	.5696	19.9970	8.561
982	5.0912	25.045	7.489	9.730	.5696	22.3216	9.024
1030	5.4907	30.029	8.937	10.850	.5696	24.3938	8.285
1071	5.8637	35.000	10.403	11.913	.5696	26.2785	9.003
1108	6.2273	40.094	11.934	12.891	.5696	28.0754	9.027

TABLE 4

11-section CW D - accelerator

λ=33cm; e/m=0.5; t=300K; k_{cap} =89.28%; J=250.0mA; η=89.28%;
P =9.215MW; J =0.280A; B =9.30T; E =4.0kV/cm; P =0.6MW;
R =1.854mm (in B=4.33T); dia.SCS=165mm; P_{RF} =ΣP_{11} =10.7MW;

SECT	CELL	E [MV/m]	W [MeV]	P [MW]	Z [m]	ϕ [rad]	L[mm]	B[T]
I	1	.4000	.796	.580	.258	1.5708		4.329
	30	.5200	.796	.598	.371	1.5708		7.548
	32	.7000	.796	.600		1.5708		7.640
	36	1.2370	.797	.601	.391	1.439		7.870
	52	1.2575	.808	.608	.455	1.415		8.214
	77	1.2940	.830	.621	.556	1.377		8.440
	127	1.3891	.894	.654	.766	1.305		8.573
	152	1.4476	.936	.673	.873	1.270		8.590
	177	1.5140	.987	.694	.984	1.235		8.596
	202	1.5868	1.048	.717	1.097	1.200		8.537
	227	1.6671	1.119	.742	1.214	1.167		8 136
	252	1.7555	1.204	.770	1.335	1.132		8.685
	277	1.8373	1.303	.802	1.461	1.099		8.963
	302	1.9108	1.419	.837	1.592	1.065		9.008
	327	1.9904	1.552	.878	1.729	1.032		9.010
	352	2.0766	1.705	.923	1.873	.9984		8.947
	398	2.2149	2.050	1.023	2.155	.9373		8.833
	477	2.4737	2.871	1.254	2.709	.8339		8.893
	477	the end of particle losses						
	502	2.5708	3.208	1.3480	2.904	.8019		8.608
	534	2.6781	3.705	1.4858	3.172	.7615		9.022
II	535	0.0000	3.700	.600	3.172	1.5708	8.65299	9.023
	539	0.0000	3.700	.601	3.206	1.126	8.65299	9.025
	540	1.7058	3.700	.605	3.214	1.122	8.66041	9.026
	581	1.8120	4.000	.686	3.576	1.032	8.99598	8.624
	633	1.9757	4.508	.825	4.057	.9267	9.54784	9.027
	673	2.1230	5.012	.962	4.450	.8528	10.0664	8.290
	706	2.245	5.516	1.099	4.789	.7964	10.55	9.025
	734	2.356	6.012	1.234	5.090	.7516	11.02	8.92
	759	2.463	6.514	1.372	5.370	.7140	11.468	8.89
	781	2.561	7.008	1.506	5.6283	.6828	11.8929	9.028
III	782	0.000	7.010	.600	5.460	1.5708	11.8929	9.027
	787	1.625	7.010	.606	5.7	1.049	11.8929	9.026
	831	1.784	7.508	.741	6.232	.9299	12.3077	8.966
	865	1.927	8.004	.876	6.656	.8498	12.7048	8.98
	894	2.061	8.512	1.013	7.030	.7895	13.1	8.96
	919	2.184	9.020	1.151	7.360	.7404	13.48	9.01
	940	2.294	9.500	1.281	7.648	.0703	13.83	8.28
	960	2.403	10.008	1.420	7.928	.6701	14.195	9.01
	978	2.505	10.510	1.555	8.180	.6425	14.540	9.01
	984	2.540	10.687	1.603	8.275	.6336	14.66	8.96
			10.6873		8.280			8.95
IV	985	0.000	10.67	.700	8.28	1.5708	14.68	8.94
	990	1.687	10.67	.707	8.36	1.045	14.68	8.74
	1013	1.782	11.01	.793	8.70	.9670	14.88	9.00
	1067	2.044	12.00	1.062	9.52	.813	15.53	9.015
	1108	2.273	13.01	1.335	10.17	.719	16.16	8.86
	1141	2.475	14.00	1.605	10.715	.6553	16.7664	8.900
	1152	2.545	14.378	1.707	10.900	.6361	16.9846	8.529
			14.3827		10.9171		17.0049	8.639
V	1153	0.000	14.38	.800	10.917	1.5708	17.0049	8.639
	1158	1.753	14.397	.809	11.002	1.042	17.0049	8.9
	1165	1.784	14.506	.839	11.121	1.014	17.0592	9.015
	1193	1.918	15.014	.978	11.602	.9111	17.3518	8.511
	1215	2.038	15.500	1.110	11.987	.8405	17.6269	9.026
	1235	2.155	16.011	1.248	12.342	.7831	17.9116	8.826
	1288	2.498	17.711	1.709	13.314	.6582	18.8255	8.623
			17.7177		13.3332		18.8450	8.727
VI	1289	0.000	17.71	.800		1.5708		8.730
	1310	1.798	18.018	.888	13.730	.9709	18.9858	9.024
	1333	1.923	18.507	1.026	14.169	.8824	19.2382	8.861
	1353	2.043	19.013	1.150	14.537	.8181	19.4849	9.023
	1386	2.261	20.020	1.430	15.207	.7202	19.9971	9.027
	1414	2.462	21.053	1.709	15.774	.6536	20.4978	8.874
			21.0627		15.7945		20.5170	8.918
VII	1415	0.000	21.06	.800		1.5708		8.92
	1420	1.606	21.080	.811	15.897	1.3820	20.5110	9.007
	1442	1.812	21.517	.930	16.350	.9371	20.7186	8.804
	1462	1.933	22.001	1.061	16.767	.8576	20.9467	9.010
	1496	2.163	23.026	1.339	17.487	.7445	21.4200	9.004
	1532	2.435	24.401	1.711	18.268	.6501	22.0383	8.994
			24.4139		18.290		22.0544	9.005
VIII	1533	0.000	24.43	.800		1.5708		9.025
	1538	1.677	24.432	.812	18.400	1.0363	22.0524	9.027
	1565	1.832	25.024	.973	18.999	.9070	22.3123	8 925
	1599	2.064	26.016	1.242	19.764	.7758	22.7406	8.848
	1626	2.271	27.011	1.512	20.384	.6928	23.1631	8.634
	1643	2.405	27.735	1.709	20.780	.6484	23.4650	9.025
			27.7504		20.8034		23.470	9.028
IX	1644	0.000	27.75	.800		1.5708		9.027
	1649	1.662	27.770	.812	20.920	1.0346	23.4793	9.025
	1661	1.731	28.004	.876	21.179	.9753	23.5757	8.659
	1724	2.184	30.003	1.420	22.712	.7158	24.3834	8.960
	1747	2.379	31.000	1.692	23.277	.6502	24.7757	9.027
			31.0644		23.4006		24.8007	9.007
X	1749	0.000	31.06	.800		1.5708		8.950
	1755	1.655	31.106	.819	23.470	1.0270	24.8169	8.960
	1790	1.867	32.022	1.069	24.349	.8486	25.1703	8.800
	1818	2.107	33.013	1.339	25.059	.7389	25.5470	8.970
	1842	2.315	34.054	1.662	25.767	.6634	25.9359	9.025

1848	2.369	34.342	1.701	25.832	.6467	26.0426	8.990
XI1849	0.000	34.36	.800		1.5708		8.902
1854	1.639	34.383	.814	25.989	1.0315	26.0577	8.601
1879	1.805	35.026	.990	26.643	.8921	26.2933	8.981
1908	2.033	36.019	1.261	27.410	.7644	26.6532	8.985
1931	2.235	37.002	1.529	28.027	.6839	27.0041	8.914
1944	2.356	37.637	1.702	28.379	.6452	27.2260	8.200
		37.6583		28.43			

TABLE 5

12-section 2-wavelength CW D - accelerator

λ=66/33cm; e/m=0.5; t=300K; k_{cap} =91.0%; J=250.0mA; η=89.0%; P =9.2MW; J =2x0.140A; B =9.30T; E =1.85kV/cm; P =0.12MW; R =2.53mm (B=4.1T); $P_{RF}=\Sigma P_{12}$ =12.1MW;

SECT	CELL	E[MV/m]	W[MeV]	P_i[MW]	Z_i[m]	ϕ[rad]	B[T]
I	1	.185	.128	.120	.258	1.5708	4.092
66cm	12	.185	.128	.121	.289	1.5708	5.314
	22	.6714	.128	.121	.317	1.4674	6.515
	52	.7080	.136	.132	.416	1.4297	7.713
	90	.7616	.152	.149	.545	1.3818	8.099
	127	.8229	.174	.169	.679	1.3346	8.212
	159	.8845	.201	.190	.804	1.2926	8.252
	231	1.0555	.301	.255	1.124	1.1926	8.167
	273	1.1841	.400	.313	1.347	1.1295	8.405
	303	1.2959	.500	.368	1.527	1.0818	8.649
	345	1.5177	.704	.475	1.818	1.0110	8.641
	384	1.7787	1.001	.619	2.139	.9407	8.446
	403	1.9281	1.200	.712	2.318	.9049	8.664
	426	2.1180	1.507	.855	2.557	.8602	8.666
	438	2.2263	1.703	.945	2.694	.8365	8.571
	450	2.3310	1.935	1.040	2.836	.8144	7.980
II	1	.6000	1.935	.998	.263	1.5708	4.534
33cm	39	1.0000	1.925	1.000	.494	1.5708	8.304
	70	2.2172	2.001	1.203	.683	1.3756	8.544
	167	2.3727	2.404	1.170	1.327	1.2161	8.654
	225	2.5082	2.802	1.302	1.747	1.1257	9.008
	248	2.5720	3.002	1.366	1.923	1.0907	8.851
	296	2.7122	3.508	1.513	2.312	1.0189	9.009
	312	2.7602	3.707	1.570	2.448	.9953	9.024

For III-XII see sections II-XI at Table 4.

TABLE 6

Varying energy in CW D-BWLAP

ϕ/π	f MHz	W MeV	dW/df	W_{10}	W_0	W_{-10}	$(W_{-10} - W_{10})/W_0$
11/12	873.0	17.51					
10/12	917.0	23.60	1.5e -1	22.1	23.6	25.1	12.8 %
9/12	982.3	33.98					

Here W_{-10} and W_{10} are the varied particle energies if the normal RF, appropriate W_0 -energy, is changed at ±10 MHz.

SOME COMMENTS ON HEAT PROCESSES IN 35 MeV CW D-BWLAP.

The operating 35 MeV deuterium CW accelerator with 0.25A beam loses about 1 MWt RF-power on waveguide inner surfaces. This heat power is dissipated primarily on AS stems. The heat value depends upon the stem location in waveguides and amounts to 10-2500 Wt per stem, which corresponds to 2x10e4- 2x10e6 Wt/m^2 heatload.

To preserve dimensions of accelerating cells at such great heat loads 3 options of the cooling system were investigated:

- the liquid flow cools the stem bottom only (Fig.1.a);
- the liquid flows along inner channels as far as the stem washer (Fig.1.b);
- the liquid surrounds the stem washer (Fig.1.c).

The cooling agent is water. Water flow velocity in the channels is up to 2 m/sec; pressure overfall in the channel is up to 2 atm; overfall between the channel wall temperature and the average water temperature can reach up to 30K; temperature gradient inside the copper wall is 5K/mm.

The stems under 2x10e4 Wt/m^2 are maximum heatloaded due to the fact that their "critical cross-section" dimensions are minimal, and the "critical" stem is the one at the injection end of AS, and the stem dimensions near the washer only are 1.8mm x 0.5mm for this case.

If channels are not made inside the stems and the heat is dissipated through the stem bottom, the temperature overfall between the top and the bottom of the stem may reach 400K.

If channels are do made inside the stems and the heat is dissipated through cooling stream to the stem bottom, the temperature falls between the top and the bottom of the stem are 50K (Fig.1b) and only 11-12K corresponding to configuration of Fig.1c.

The stem top displacement when the temperature overfall between the top and the bottom is 50K will be 17 x 10e-6 m.

The maximum temperatures corresponding to three option of designed cooling systems are shown at the said above Figs:1a, 1b, and 1c.

These systems of the D-BWLAP as a whole consist of input and output collectors in the accelerating waveguides connected with stem cooling channels. Water consumption for the whole system is 25 kg/sec. Water pressure overfall between the input and output collectors is not more than 10 atm.

The development of AS operating system should be based upon experimental data on hydraulics and heat transfer in the stem channels.

CONCLUSION

In February this year the colleagues from Grumman Airspace and Electronics had familiarized us with the detailed history of the FMIT and its characteristics as well as the IFMIF - project. The "PhysTech Instrument" has carefully studied the materials, evaluated them as "A Challenge" for research brains, and as "A Touchstone" for BWLAP approach.

We have come to conclusion that we may consider the Grumman's papers as request to exceed the main parameters of FMIT, IFMIF, and ESNIT.

This is the draft result of our first attempt to investigate the problem.

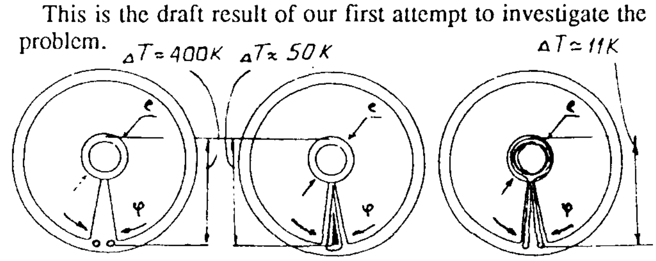

Fig. 1a. Fig. 1b. Fig. 1c.