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A. CONTRACT LINE ITEM NO. 0001AA B. EXHIBIT A C. CATEGORY: TDP _____ TM _____ OTHER TECHNICAL REPORTS

D. SYSTEM/ITEM Inexpensive E. CONTRACT/PR NO. N00014-92-C-2218 F. CONTRACTOR MOXTEK

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16. REMARKS

THIS REPORT IS TO PROVIDE INFORMATION REGARDING PROGRESS UP TO DATE.

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G. PREPARED BY H. DATE I. APPROVED BY J. DATE

INEXPENSIVE CAPILLARY DISCHARGE X-RAY LASER DRIVER.

INITIAL TECHNICAL REPORT FOR PHASE I

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A fully-implicit code to time-advance the 1-D MHD equations has been developed up to date specifically for modelling a capillary discharge (a radial dependence of parameters). Classical transport is assumed to have the correct dependence to within a multiplicative factor that can be specified at run-time. The atomic physics of the plasma is modelled using 0-D approximation where an "average" temperature and density are used to determine the ionization and recombination rates for the principal plasma species. These rates are then used to determine an "effective z " for the MHD model. It is assumed that the entire plasma is ionized to the same state. The model can currently treat elements up to $z=18$ (argon) due to limitations in the atomic physics portion of the code.

The code has been tested using some published data from carbon capillaries [2,4] and the best fit corrections to classical transport have been determined for that type of discharge. Normalization of the code for an argon plasma has not been done due to a lack of published experimental capillary discharge data.

An extensive literature search for the previous capillary discharge experiments was performed and the result of this search is summarized in the Table 1. These experiments cover a plasma temperature range $T_e = 1-100$ eV and a plasma electron density range $N_e = 10^{17}-10^{20} \text{ cm}^{-3}$.

From the point of view of plasma parameters a capillary discharge stays between z-pinch discharge ($T_e > 100$ eV, $N_e > 10^{20} \text{ cm}^{-3}$) and high current ion laser discharges ($T_e < 10$ eV, $N_e < 10^{15} \text{ cm}^{-3}$).

In paper [4] the authors claimed they had registered the bursts of an amplified spontaneous emission (ASE) at 18.22 nm 3-2 transition in a H-like C. Authors estimated a gain $\alpha \cong 2-3 \text{ cm}^{-1}$. The bursts were very short (a few nsec), not reproducible well, and they occurred only in the middle of a second half-period of the discharge. According to [4], increasing or decreasing the capacitance of discharge capacitor or inductivity of a discharge circuit depressed the occurrence of the bursts. No spectra of emitted lines were presented in the paper and no plasma diagnostics was performed.

In paper [9] a very high plasma temperature (100 eV) and density (10^{20} cm^{-3}) were reported for fluorine plasma, but it was not clear what was the feature size of such hot and dense plasma. These parameters are more likely connected with hot microscopic plasma volumes rather than with a bulk plasma. No spatially resolved diagnostics were reported here.

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Table 1. Summary of various capillary discharge experiments to date. Here: U_0 , C_0 , L_0 , - discharge set parameters; I_0 - peak discharge current; j_0 - peak current density, Z - discharge impedance, $Z = \sqrt{L_0/C_0}$; E_0 - stored energy; $t/4$ - discharge current rising time; τ - discharge current exponential decay time; $d \times l$ - capillary geometry (diameter $\times$ length); W - energy contribution into plasma (J/cm^3), $W = E/V$; P - power contribution into plasma (W/cm^3) $P = W/\tau$; T_e - plasma electron temperature (eV); N_e - plasma electron density (cm^{-3}).

Ref #	U_0 (kV)	C_0 (μF)	I_{max} (kA)	j_{max} (MA/cm ²)	L_0 (nH)	Z (Ohm)	E_0 (J)	$t/4$ (ns)	$d \times l$ (mm $\times$ mm)
1	40	0.3	36	1	200	1.1	240	400	2x20
1	40	0.3	-	-	200	1.1	240	-	2x20
2	35	0.05	50	24	20	0.6	30	50	0.5x20
2	15	0.05	20	10	20	0.7	6	50	0.5x20
3	40	0.3	-	-	-	-	240	300	2x20
4	7	0.1	14*	2	15	0.5*	2.5	130	1x10
4	9	0.1	14*	8	15	1*	4.1	130	0.5x20, 30
5	20	0.004	1.2	0.15	10	15*	0.8	50	1x300
6	10	0.12	5	0.01	600	2	6	400	7x1500
7	10	0.03	2	0.004	600	-	0.4	-	7x1500
8	25	0.12	-	-	80	2	38	-	0.4x13
9	250	-	100	10 ⁴	-	3	-	10	1x10

*) calculated value

Table 1. (cont.)

Ref #	τ (ns)	W (KJ/cm ³)	P (GW/cm ³)	T_e (eV)	N_e (10 ¹⁹ cm ⁻³)	$W \times N_e$ (KeV)	Element	Ion
1	1000	4	4	25	1	6	C	-
1	1000	4	4	12	0.7	9	Li	-
2	100	8	80	38	2.5	5	C	H, He
2	100	1.6	16	25	1.5	2	C	H, He
3	1000	4	4	20	0.6	11	Li	H, bare
4	250	0.3	1.2	-	-	-	C	H
4	250	1	4	-	-	-	C	H
5	90	3x10 ⁻³	0.03	16*	0.01	0.5	He	H-,
6	600	1x10 ⁻⁴	1.6x10 ⁻⁴	3*	-	-	Kr	3+, 4+
7	-	5x10 ⁻⁶	-	5*	-	-	Ne	3+
8	200	23	110	20*	5*	7	O*	4+*
9	-	-	-	150*	10*	-	F*	H, He*

*) At a current exceeding 10² KA a plasma in a capillary discharge collapses and noted parameters (as well as the ionization power) do not reflect parameters of a bulky plasma.

*) calculated values

References for Table 1.

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