

高濃度ハロゲン化アルカリ金属 水溶液からのパルスX線発生

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東北大学 大学院理学研究科 化学専攻

第9回「フロンティア先端科学」特別討論会 平成14年11月18-19日 組織化学研究所 多治見

Various Phenomena Depending on Laser Power

conventional photochemistry / photophysics
interactions between excited states

Laser Ablation

white light continuum/plasma formation

X-ray Generation

electron pulse generation

neutron pulse generation

Laser Power

0. Introduction: why do we need X-ray pulses ?

The previous works on ns & fs laser ablation of liquids

1. Various X-ray Pulse Sources

photo-excitabile X-ray tube

X-ray pulse generation from electrolyte aqueous solutions

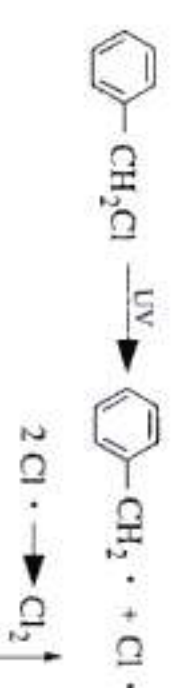
X-ray pulse generation from Fe tape

2. Trial experiments of time-resolved X-ray structure analyses

3. Summary

Nanosec & Femtosec UV Laser Ablation of Organic Liquids

30 ns, 248 ns, or
300 fs, 248 ns /Ti:S/KrF Hybrid System at JAERI



Ultrafast time-resolved spectroscopy for molecular processes

Koji HATANAKA, *et al.*, *J. Phys. Chem. B, Feature Article*, 106, 3049, 2002

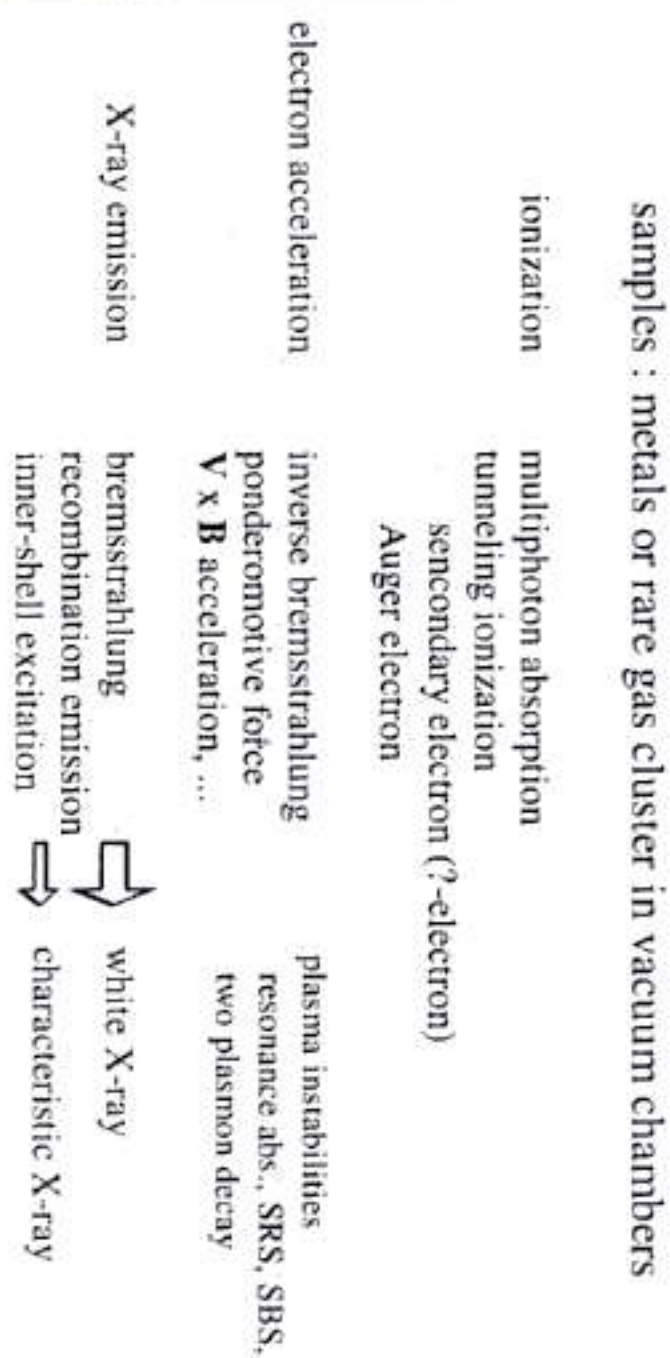
Toward X-ray Structure Analyses



For Practical Applications & Science

- Point Light Source
- Recyclable
- Endurable
- No Vacuum Chamber
- Different Type of Materials Other than Metals or Gases
- Water**

Introduction to Laser Plasma X-ray



Solutions

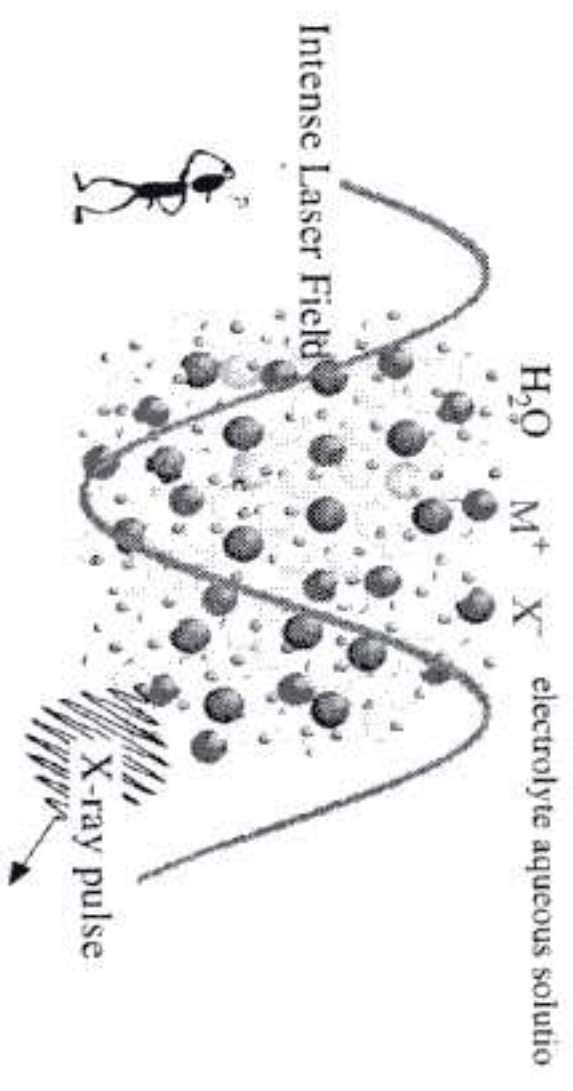
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11	Na	12	Mg	13	Al	14	Si	15	P	16	S	17	Cl	18	Ar	19	K	20	Ca
21	Sc	22	Ti	23	V	24	Cr	25	Mn	26	Fe	27	Co	28	Ni	29	Cu	30	Zn
31	Ga	32	Ge	33	As	34	Se	35	Br	36	Kr	37	Rb	38	Sr	39	Y	40	Zr
41	Nb	42	Mo	43	Tc	44	Ru	45	Rh	46	Pd	47	Ag	48	Cd	49	In	50	Sn
51	Sb	52	Te	53	I	54	Xe	55	Cs	56	Ba	57	La	58	Ce	59	Pr	60	Nd
61	Pm	62	Sm	63	Eu	64	Gd	65	Tb	66	Dy	67	Ho	68	Er	69	Tm	70	Yb
71	Lu	72	Hf	73	Ta	74	W	75	Re	76	Os	77	Ir	78	Pt	79	Au	80	Hg
81	Tl	82	Pb	83	Bi	84	Po	85	At	86	Rn	87	Fr	88	Ra	89	Ac	90	Th
91	Pa	92	U	93	Np	94	Pu	95	Am	96	Cm	97	Bk	98	Cf	99	Es	100	Fm
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111	Gd	112	Tb	113	Dy	114	Ho	115	Er	116	Tm	117	Yb	118	Lu	119	Ac	120	Th
121	Pa	122	U	123	Np	124	Pu	125	Am	126	Cm	127	Bk	128	Cf	129	Es	130	Fm
131	Md	132	No	133	Lr	134	La	135	Ce	136	Pr	137	Nd	138	Pm	139	Sm	140	Eu
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271	Pa	272	U	273	Np	274	Pu	275	Am	276	Cm	277	Bk	278	Cf	279	Es	280	Fm
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391	Pa	392	U	393	Np	394	Pu	395	Am	396	Cm	397	Bk	398	Cf	399	Es	400	Fm
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441	Gd	442	Tb	443	Dy	444	Ho	445	Er	446	Tm	447	Yb	448	Lu	449	Ac	450	Th
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771	Gd	772	Tb	773	Dy	774	Ho	775	Er	776	Tm	777	Yb	778	Lu	779	Ac	780	Th
781	Pa	782	U	783															

Introductory Exploring PW Solution Physical Chemistry

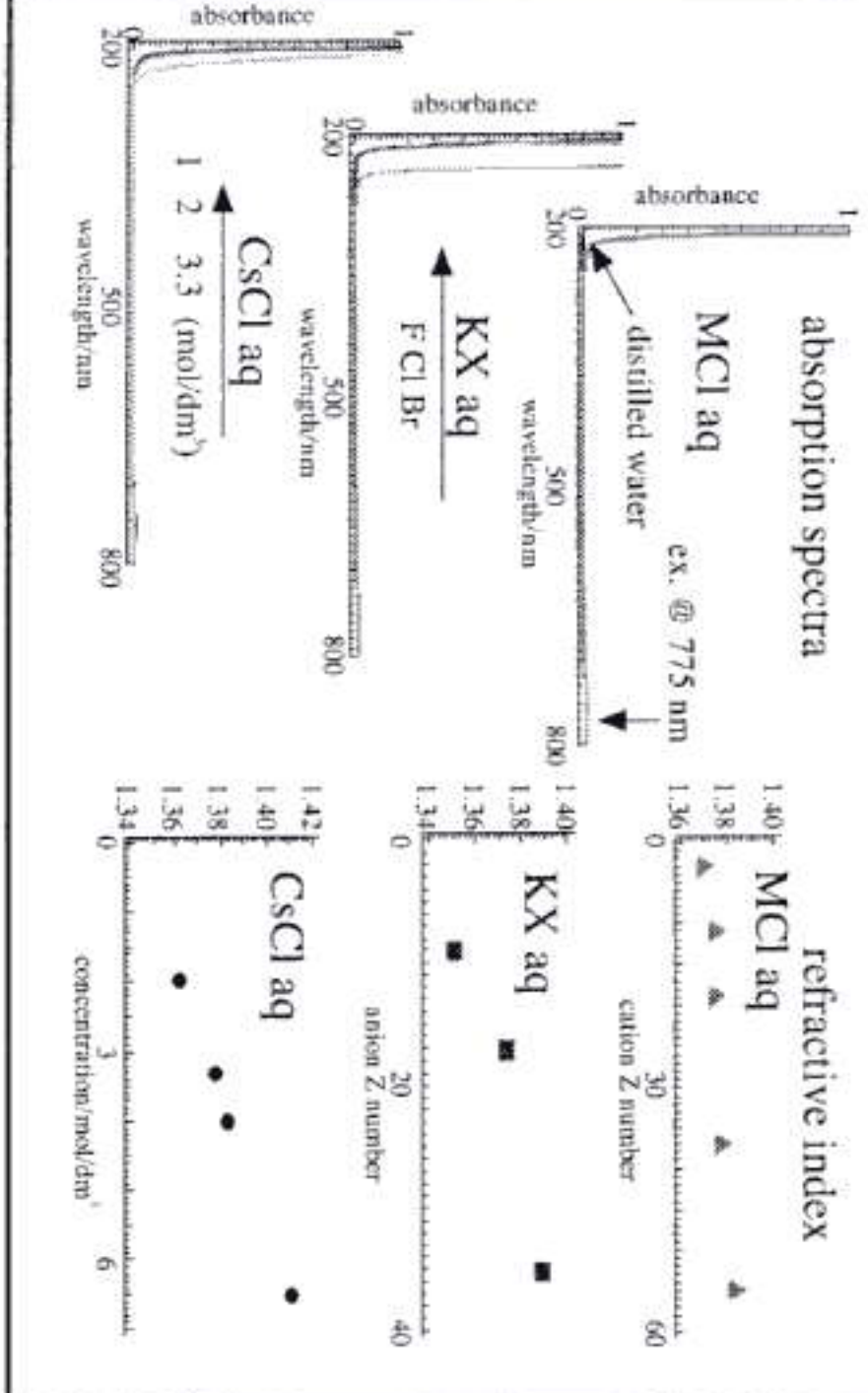
PW Solution Physical Chemistry

potential distortion/Debye-Huckel theory
solvated/wet electrons
Water
chemical reactions

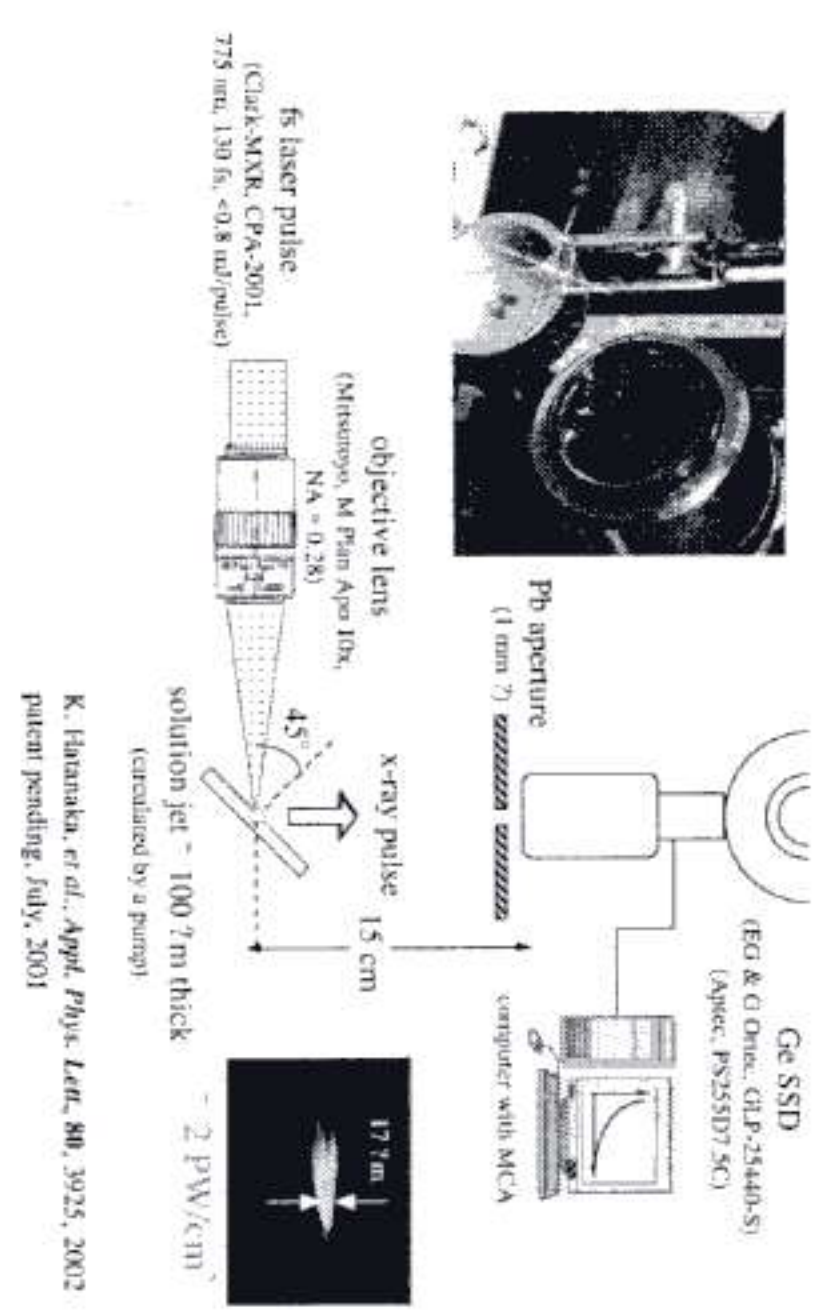
high-energy electron life time / X-ray pulse width controllable ?



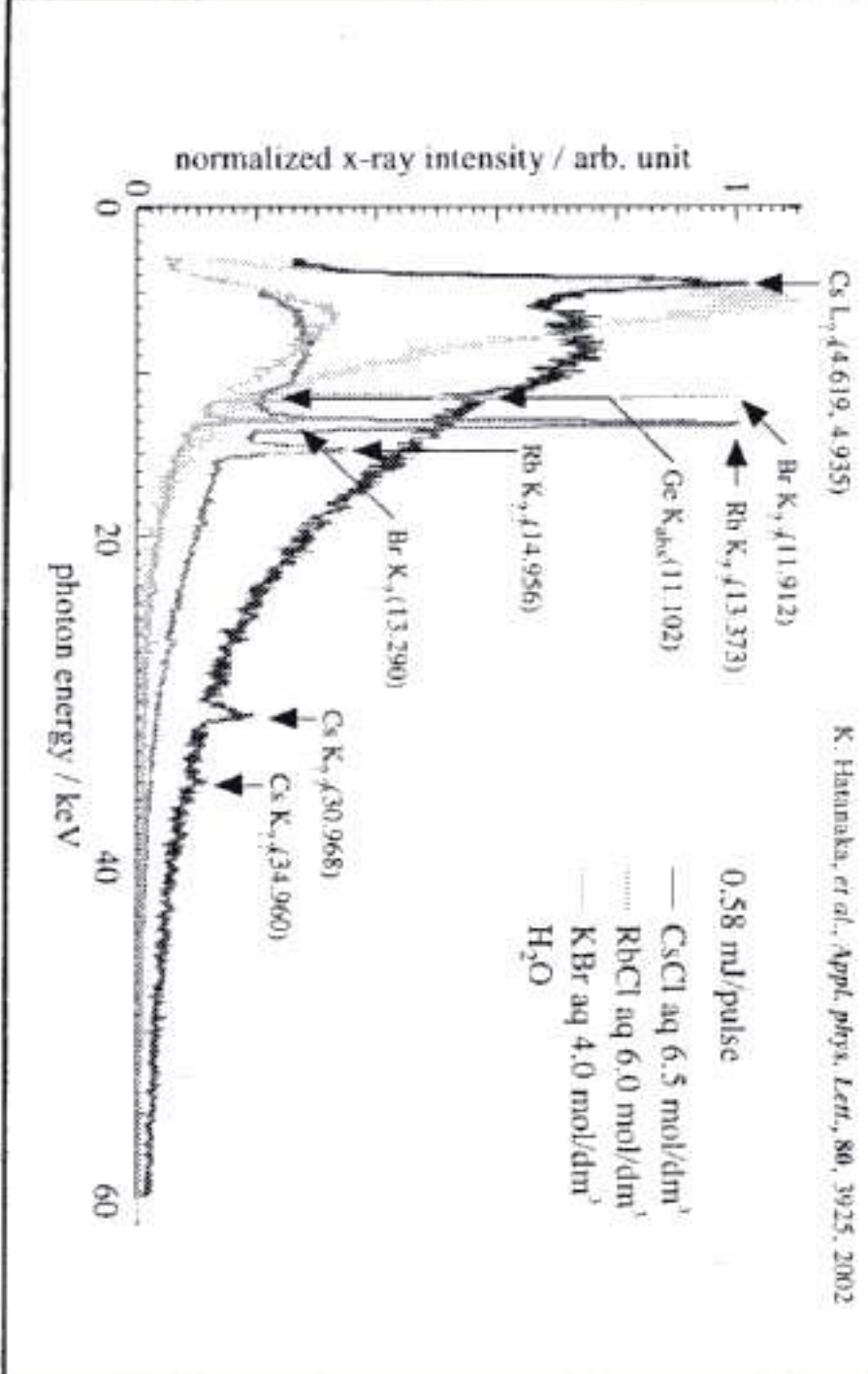
Sample Solutions / Characteristics



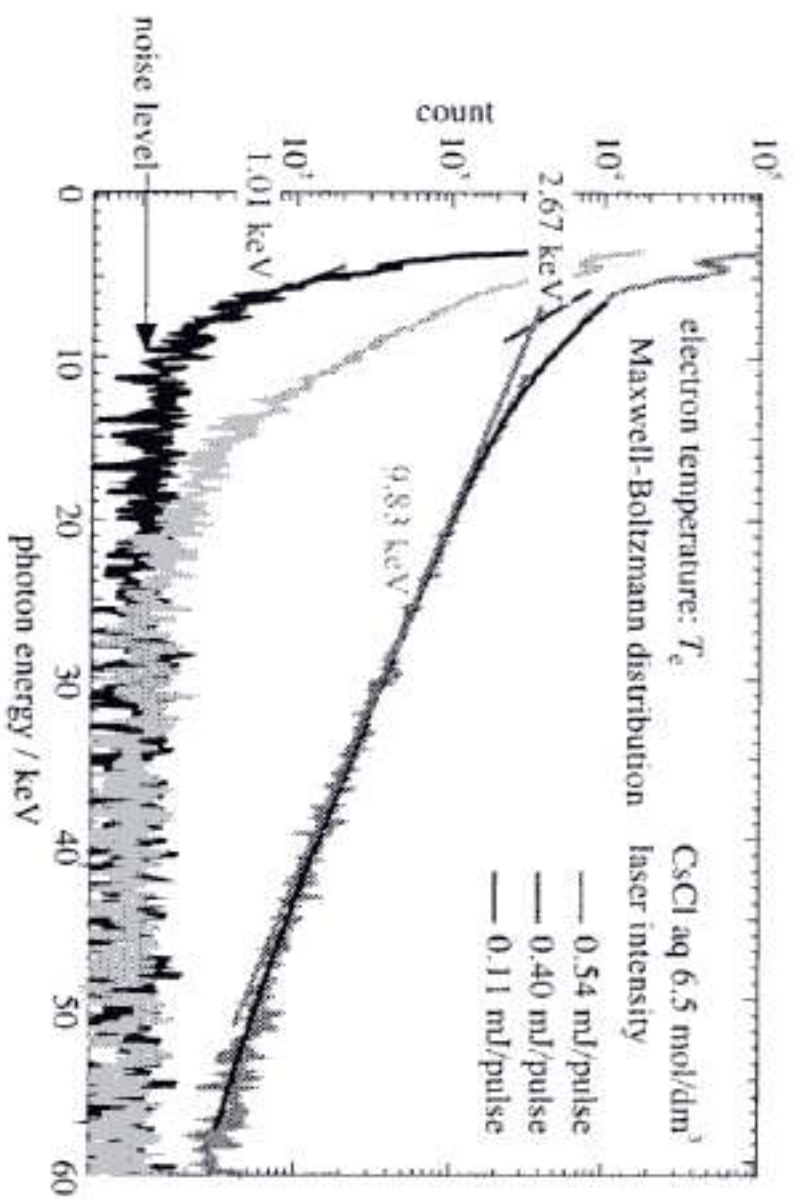
Experimental Setup for X-ray Emission Spectroscopy



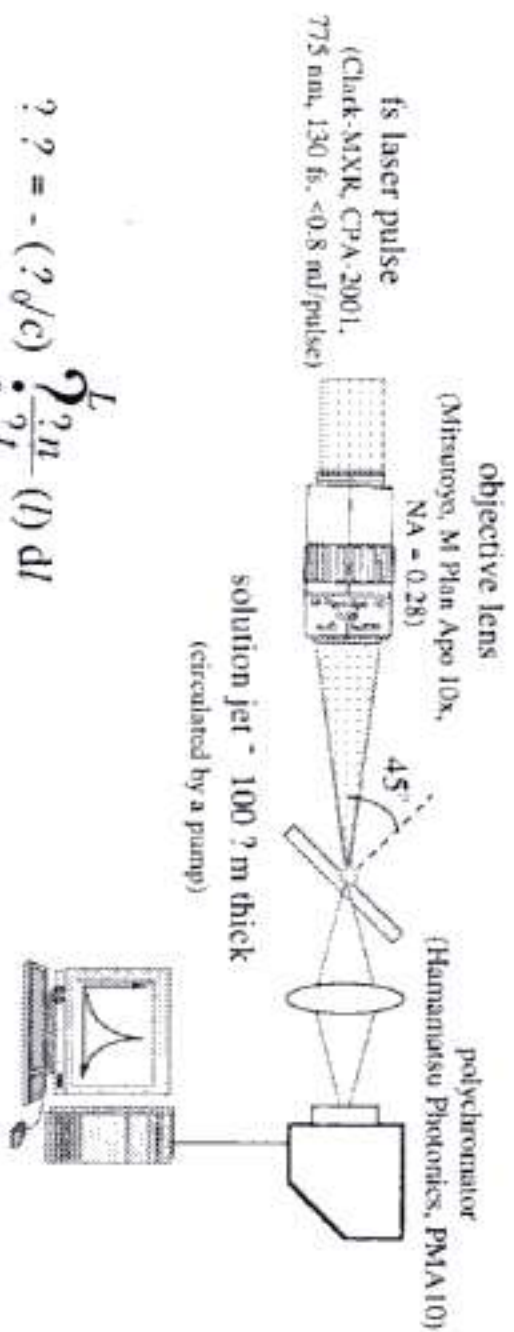
X-ray Emission Spectra



X-ray Emission Spectra / Laser Intensity Dependence



Experimental Setup for Transmitted-Laser Spectroscopy

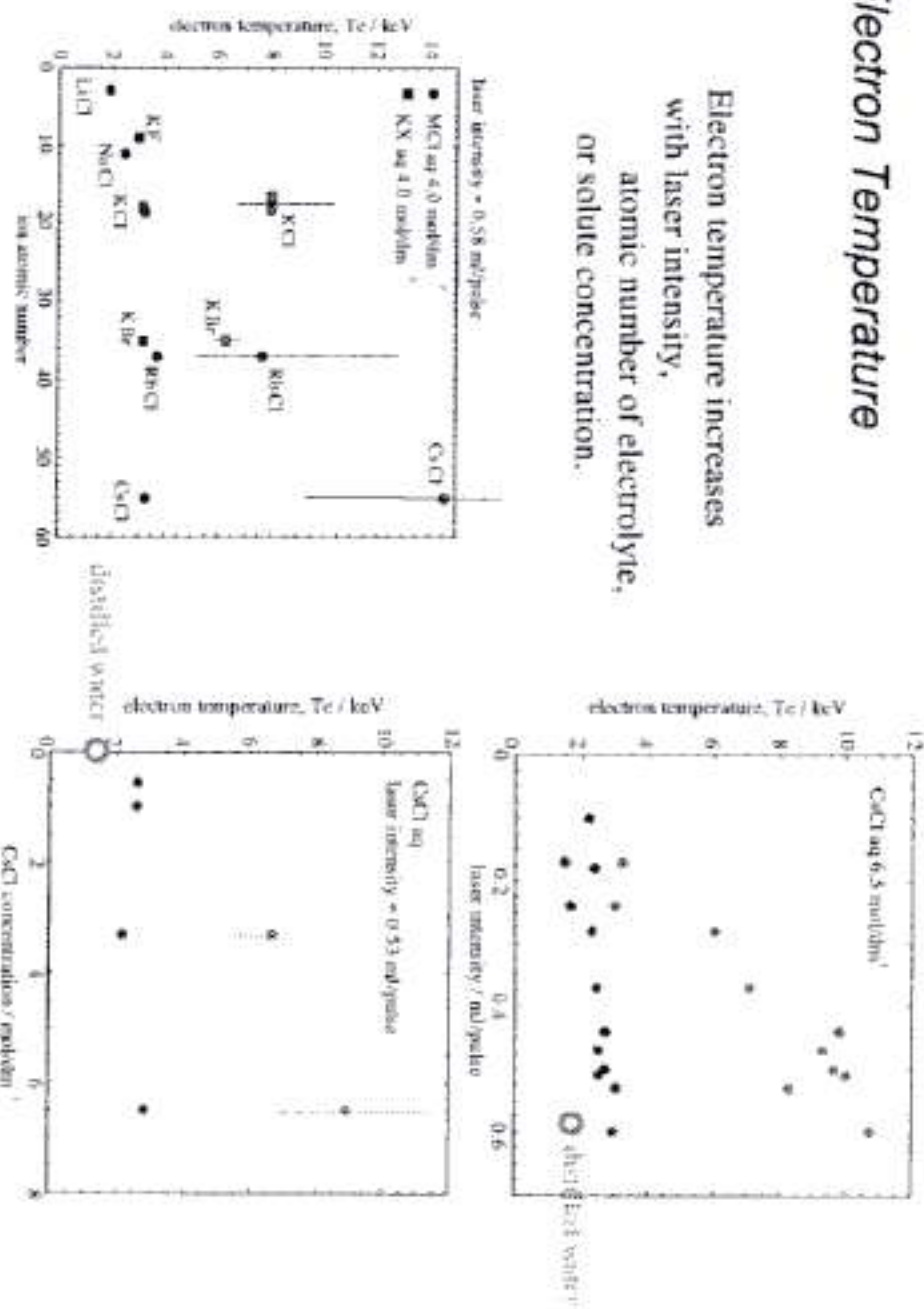


$$I = -\left(\frac{dI}{dz}\right) \cdot \frac{z}{I} \cdot (I) \cdot dz$$

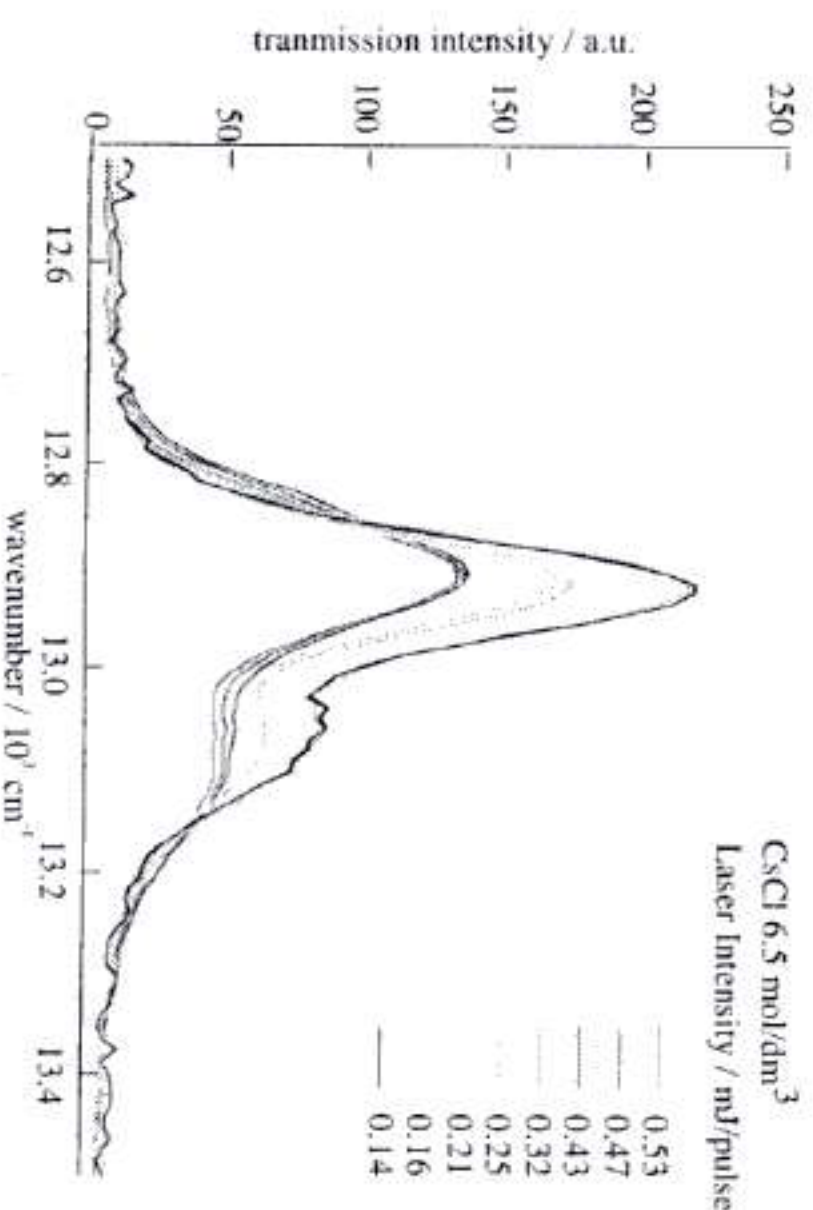
M. C. Downer, et al., *IEEE Transactions on Plasma Science*, 21, 20, 1993

Electron Temperature

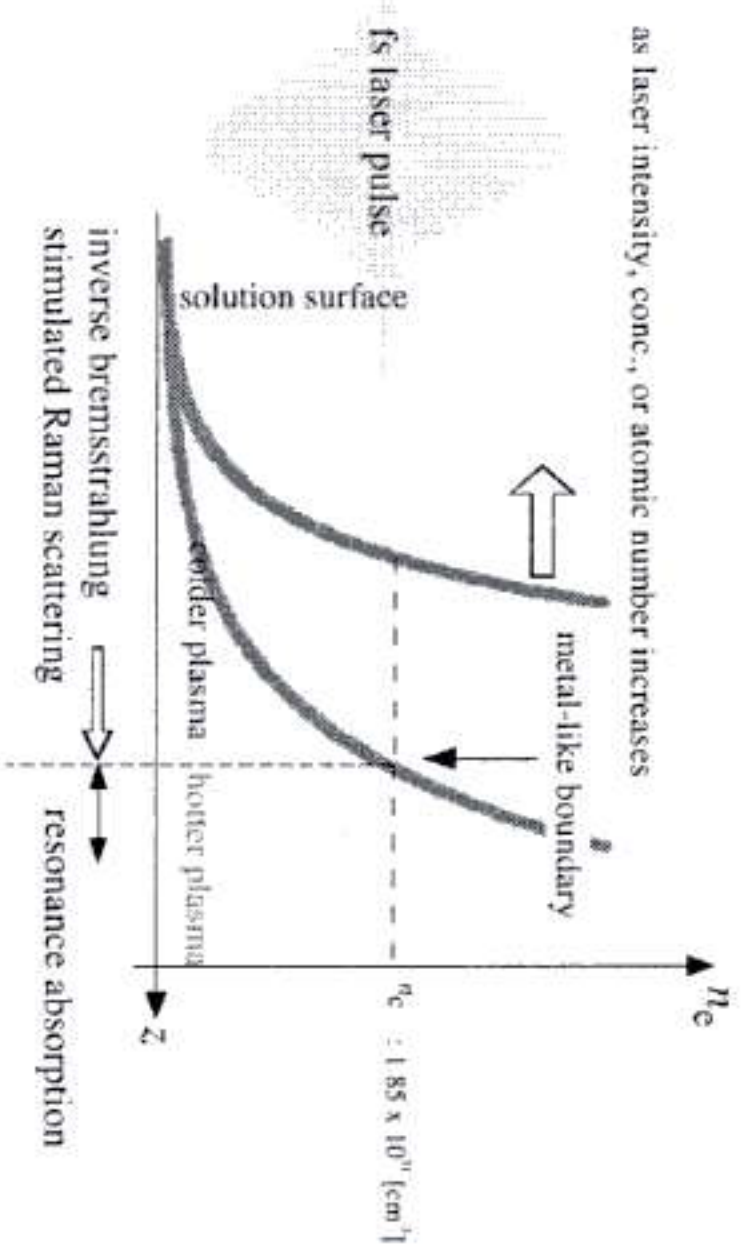
Electron temperature increases with laser intensity, atomic number of electrolyte, or solute concentration.



Frequency Blue Shift of Transmitted Laser Pulses



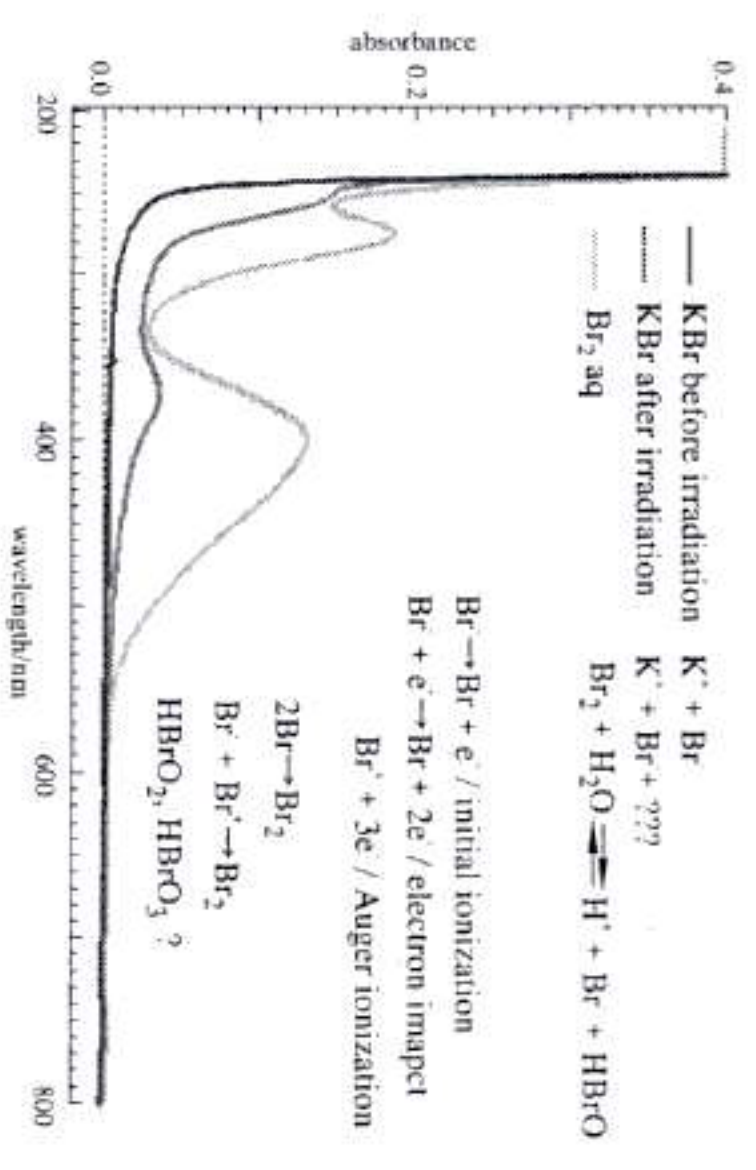
Conventional Laser Plasma Physics



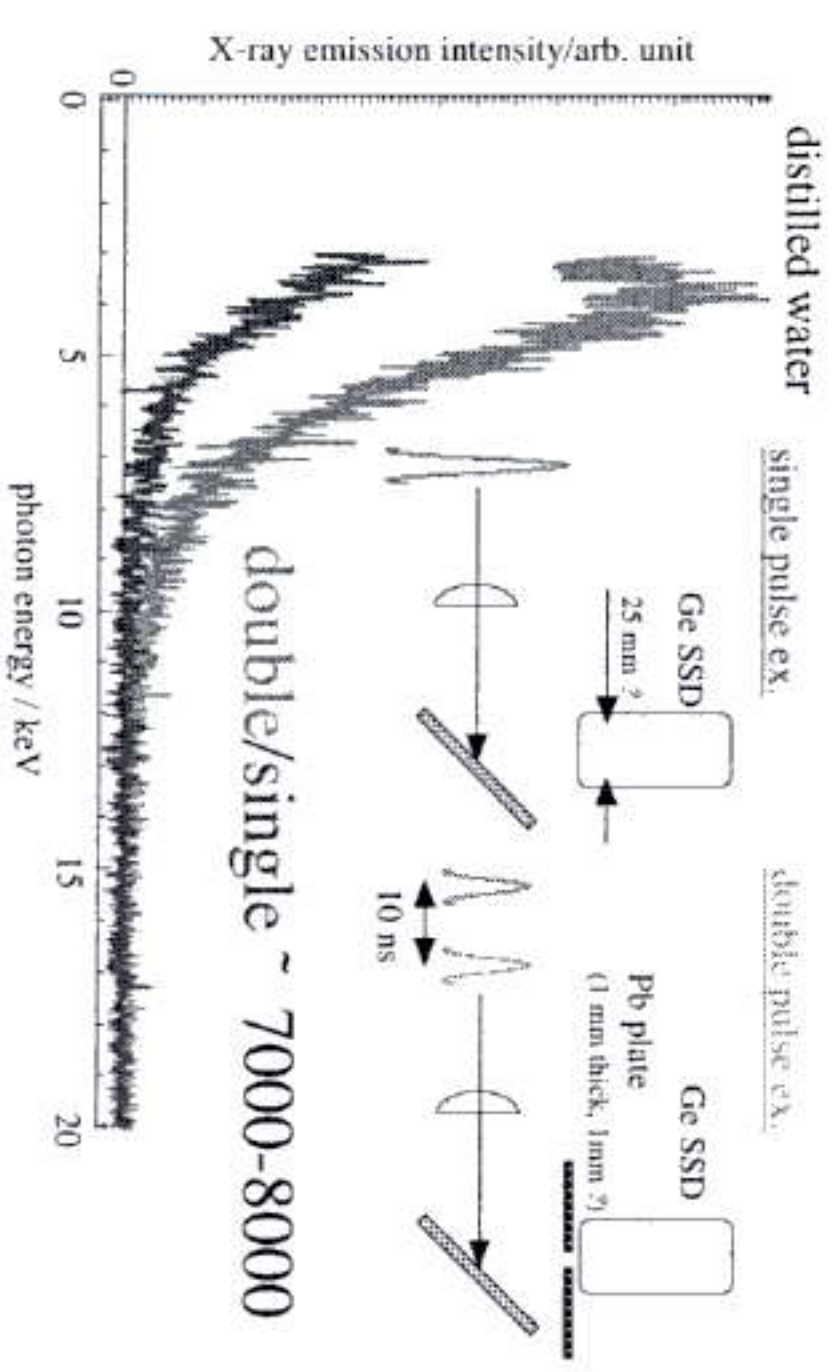
Information on X-ray Pulse Generation Dynamics is Needed.

Are not There Any Other Possibilities for Electrons to Absorb Laser Energy ?

Chemical Reactions in PW Laser Field



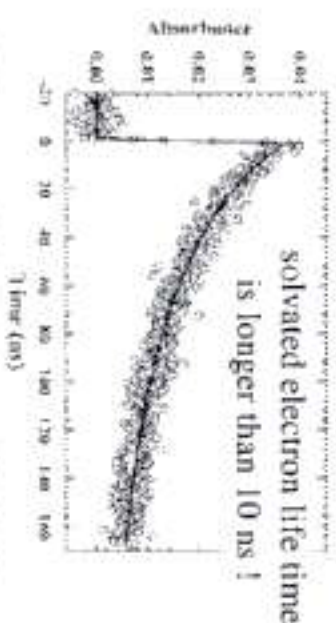
Double Pulse Excitation / X-ray Intensity Enhancement



Double Pulse Excitation / Discussion



plasma emission life time < 1-2 ns
(confirmed by streak camera)



S. Pommeroy, *et al.*, *Rev. Chem. Intermed.* 27, 901, 2001

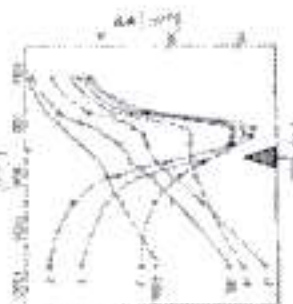


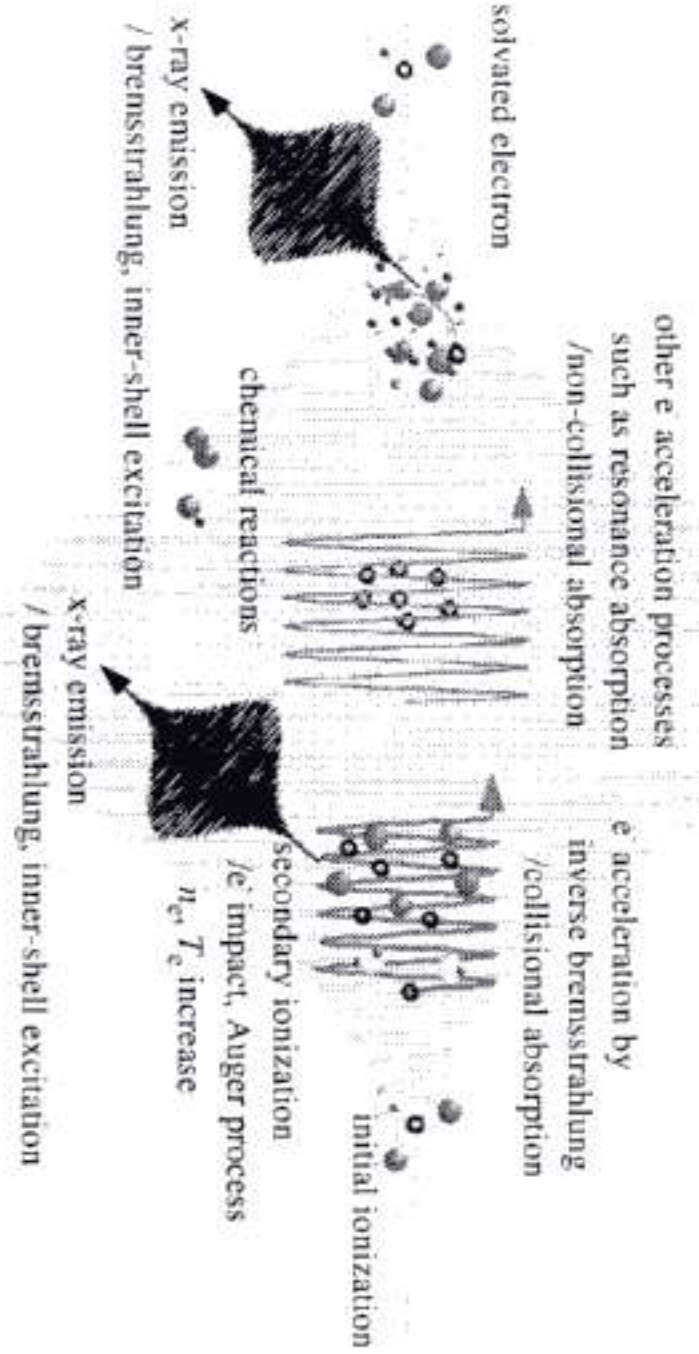
Fig. 1. Absorption spectra of the electron in different solvents at 775 nm. The absorption spectra were recorded in a quartz cell of 1 cm thickness. The concentration of the electron was 1.85×10^{21} cm⁻³. The absorption spectra were recorded at 775 nm.

solvated electrons absorb laser energy more efficiently? \Rightarrow time-resolved absorption spectroscopy

A. Avroni, *et al.*, *PRL*, 58, 1559, 1987

Possible Mechanisms for X-ray Pulse Generation

$$n_e \geq n_c = 1.85 \times 10^{21} \text{ [cm}^{-3}\text{] @ 775 nm}$$



Solvated Electrons / Time-resolved Absorption Spectroscopy

