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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第5回「プラズマと物質科学」研究討論会 平成14年11月18-19日 核融合科学研究所 多治見

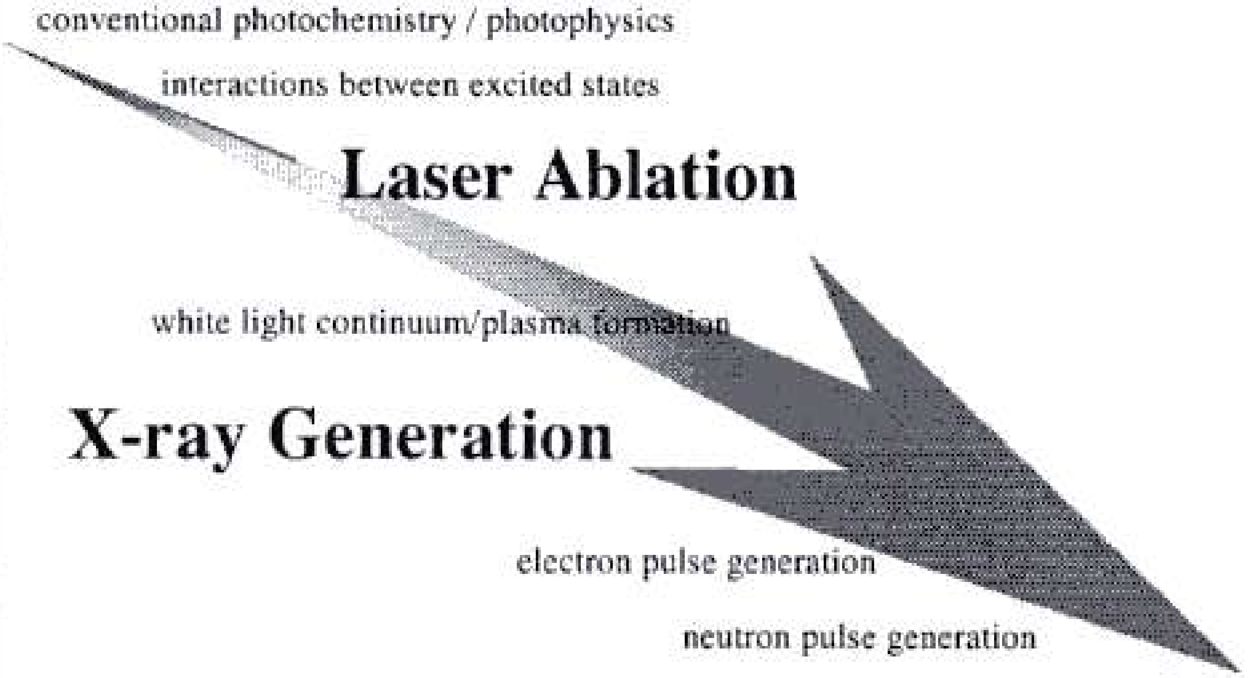
0. Introduction: why do we need X-ray pulses ?
   The previous works on ns & fs laser ablation of liquids

1. Various X-ray Pulse Sources
   photo-excitable 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

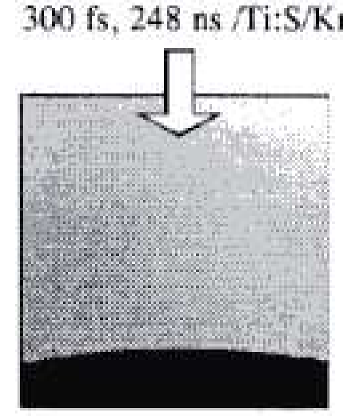
3. Summary

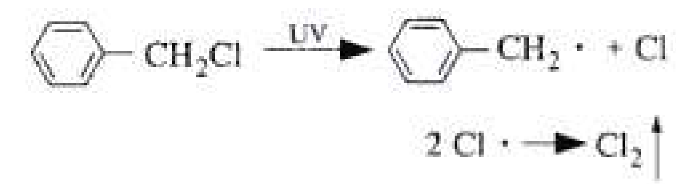
Various Phenomena Depending on Laser Power



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

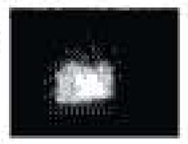
Toward X-ray Structure Analyses

ps-fs time-resolved X-ray structure analysis

X-ray diffraction, X-ray absorption fine structure
X-ray emission spectroscopy, X-ray fluorescence holography
X-ray photoelectron spectroscopy, Auger electron spectroscopy
X-ray photoelectron diffraction

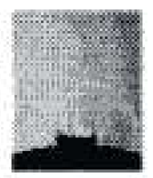
ps time-resolved surface scattering imaging

K. Hatanaka, *et al.*, *Appl. Phys. Lett.*, 73, 3498 (1998)
K. Hatanaka, Y. Tsuboi, *et al.*, *J. Phys. Chem.* **B 106**, 3049 (2002)



ns time-resolved shadowgraphy

K. Hatanaka, *et al.*, *J. Appl. Phys.*, **82**, 5799 (1997)
K. Hatanaka, Y. Tsuboi, *et al.*, *J. Phys. Chem.* B 106, 3049 (2002)



Introduction to Laser Plasma X-ray

samples : metals or rare gas cluster in vacuum chambers

ionization
- multiphoton absorption
- tunneling ionization
  - sencondary electron (?-electron)
  - Auger electron

electron acceleration
- inverse bremsstrahlung
- ponderomotive force
- **V** x **B** acceleration, ...

plasma instabilities
- resonance abs., SRS, SBS,
- two plasmon decay

X-ray emission
- bremsstrahlung
- recombination emission ⇒ white X-ray
- inner-shell excitation ⇒ characteristic X-ray

For Practical Applications & Science

Point Light Source

Recyclable

Endurable

No Vacuum Chamber

Differenat Type of Materials Other than Metals or Gases

Water

Solutions

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																	He
2	**Li**	Be											B	C	N	O	**F**	Ne
3	**Na**	Mg											Al	Si	P	S	**Cl**	Ar
4	**K**	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	**Br**	Kr
5	**Rb**	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	**Cs**	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt									

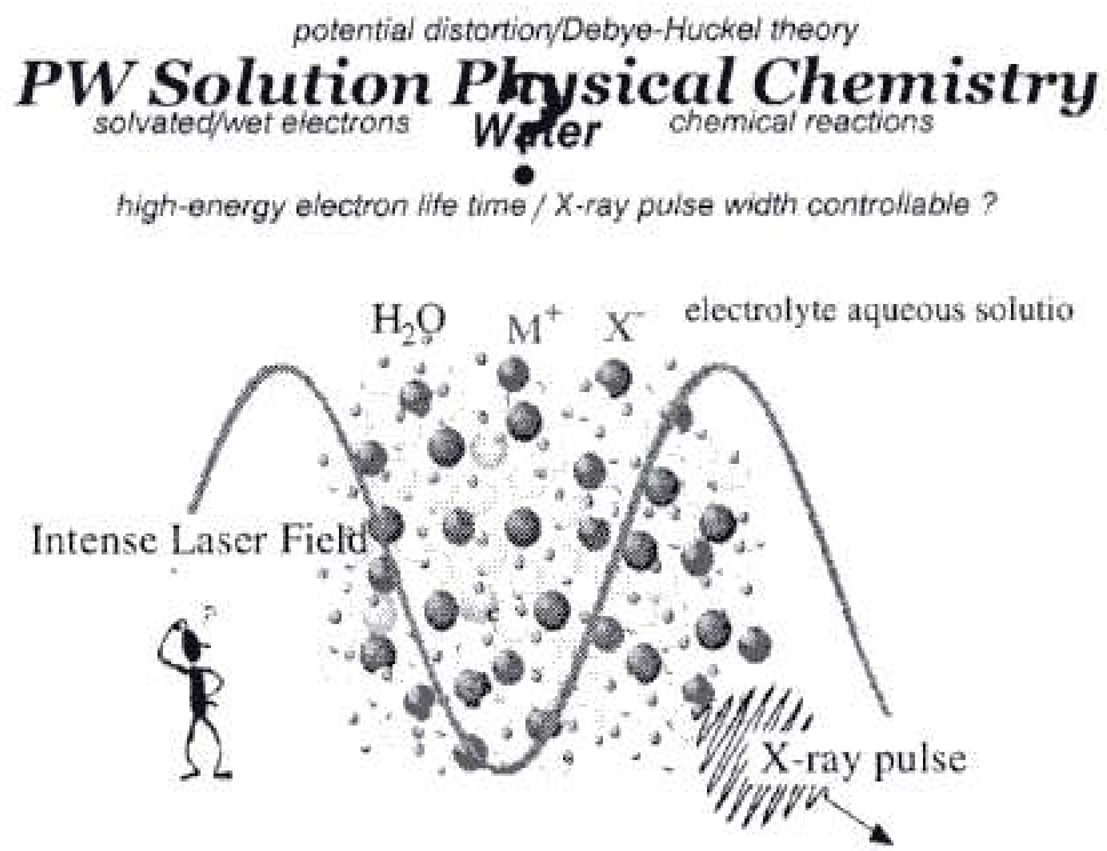
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
Ac Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr

$M^+ X^-$ Aqueous Solutions

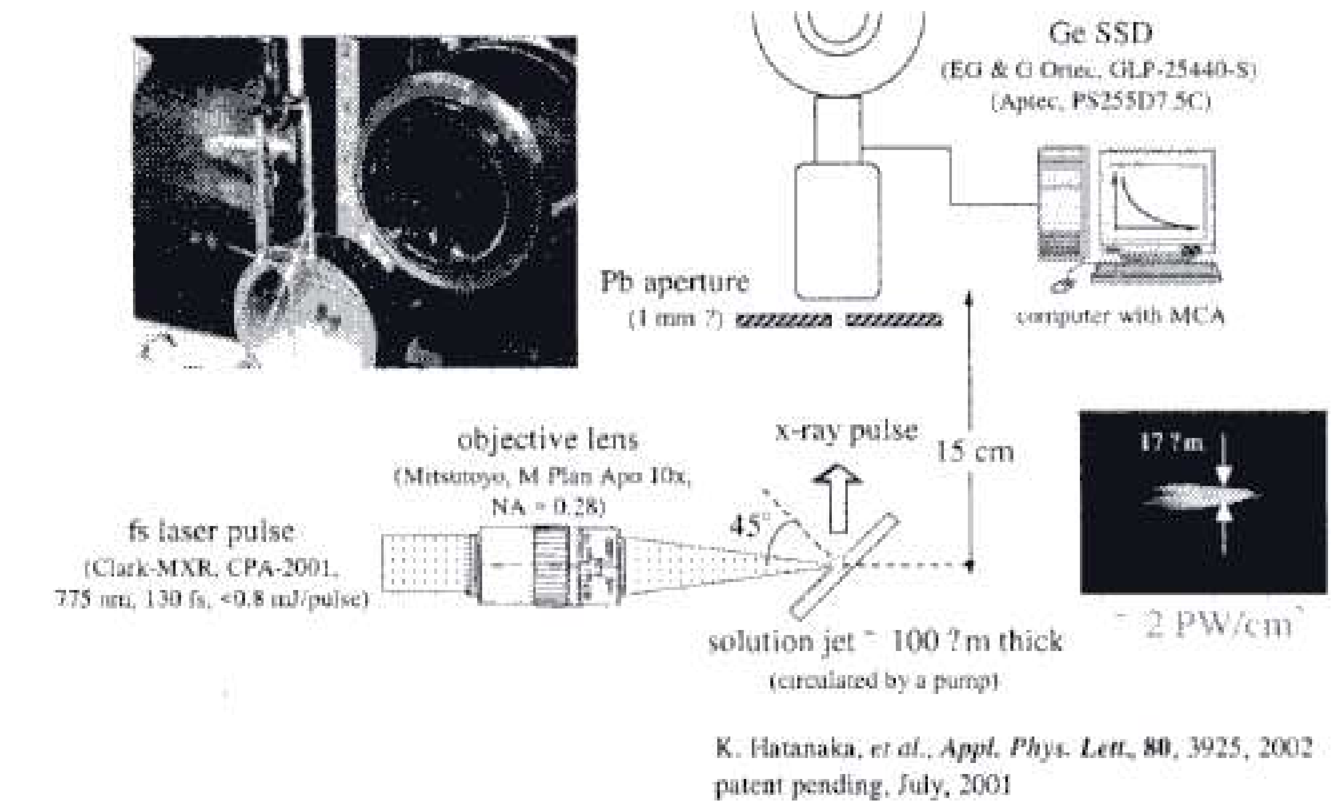
High Solubility / Wide Range of Concentration

Various Combinations of Cations and Anions

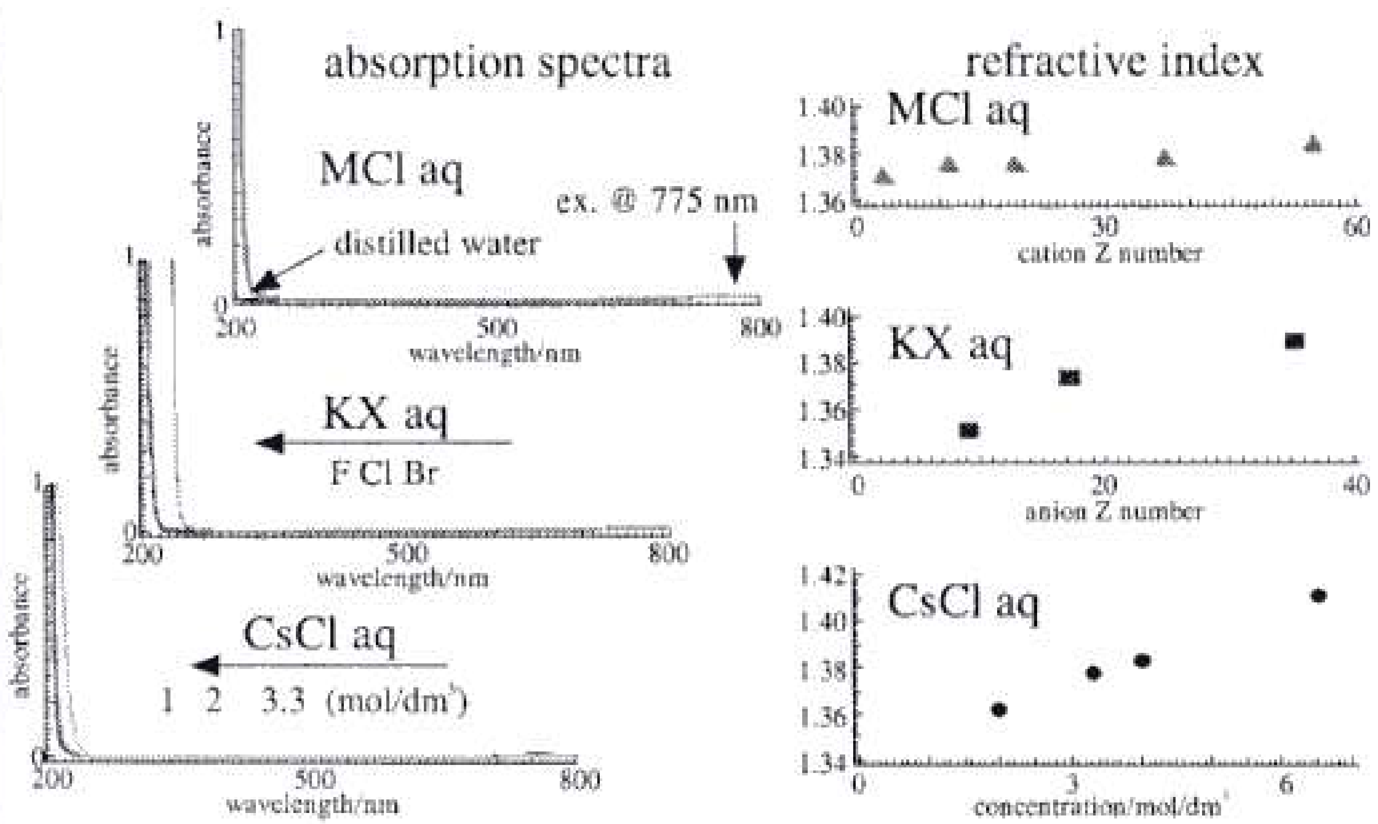
Introduction/ Exploring PW Solution Physical Chemistry



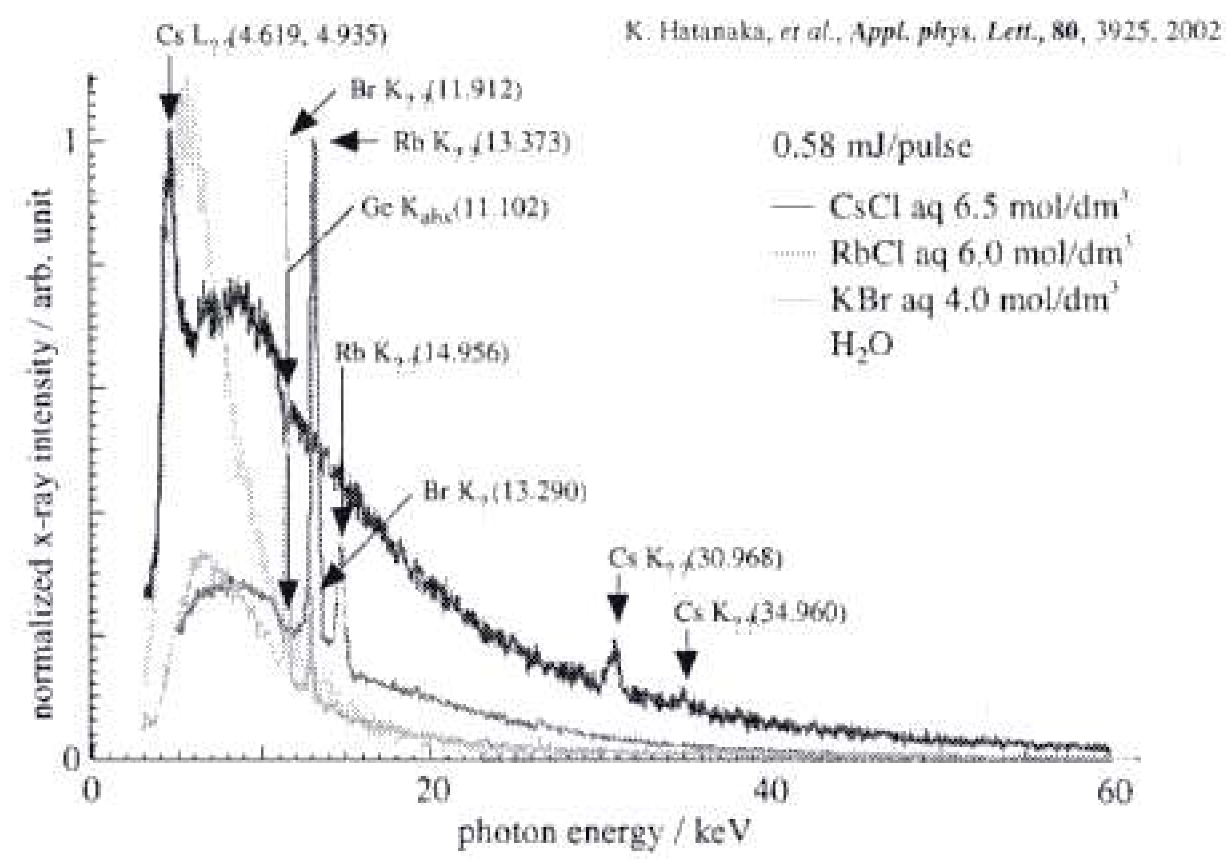
Experimental Setup for X-ray Emission Spectroscopy



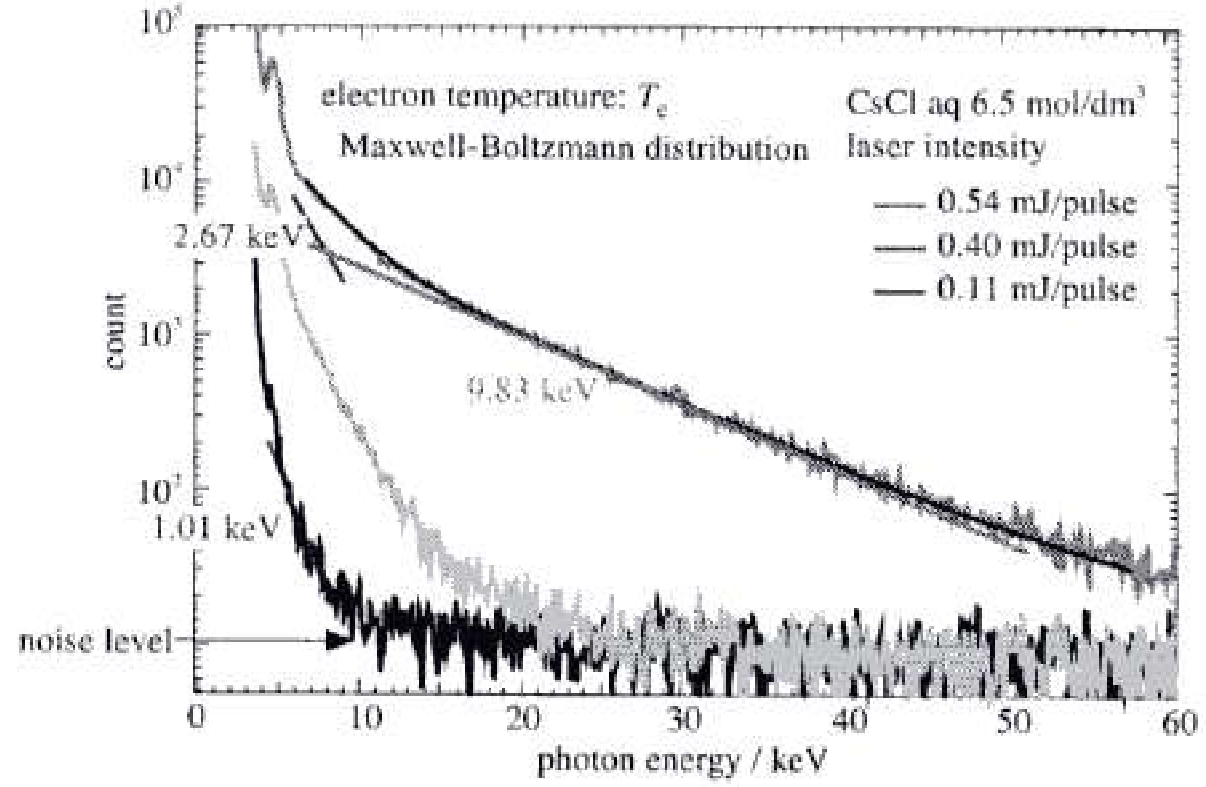
Sample Solutions / Characteristics



X-ray Emission Spectra

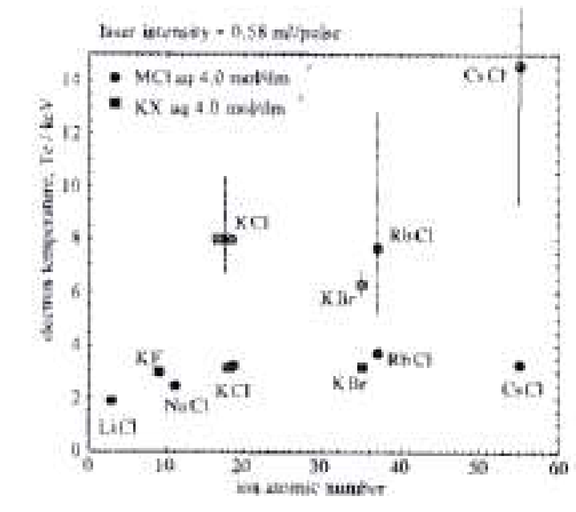


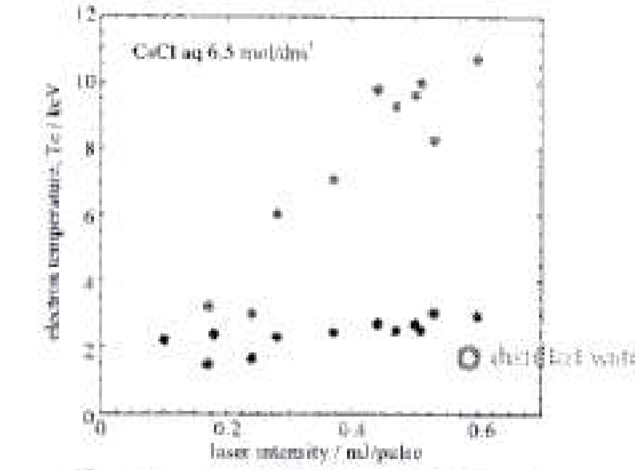
X-ray Emission Spectra / Laser Intensity Dependence

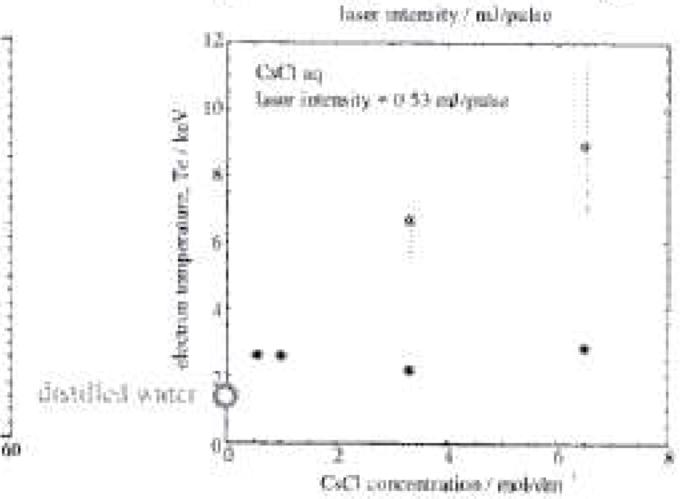


Electron Temperature

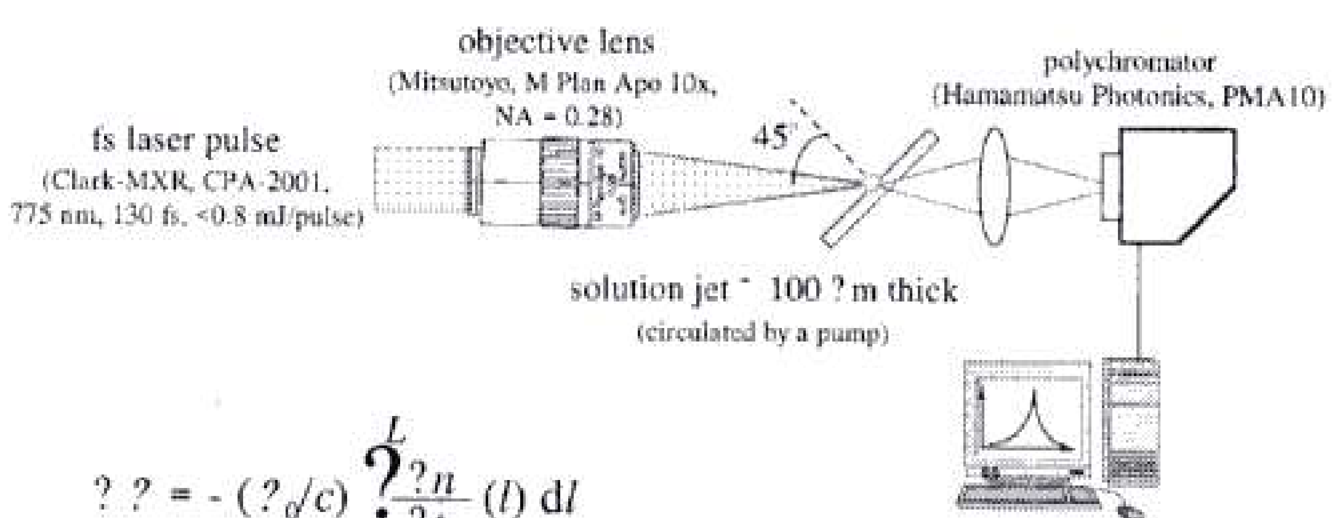
Electron temperature increases
with laser intensity,
atomic number of electrolyte,
or solute concentration.







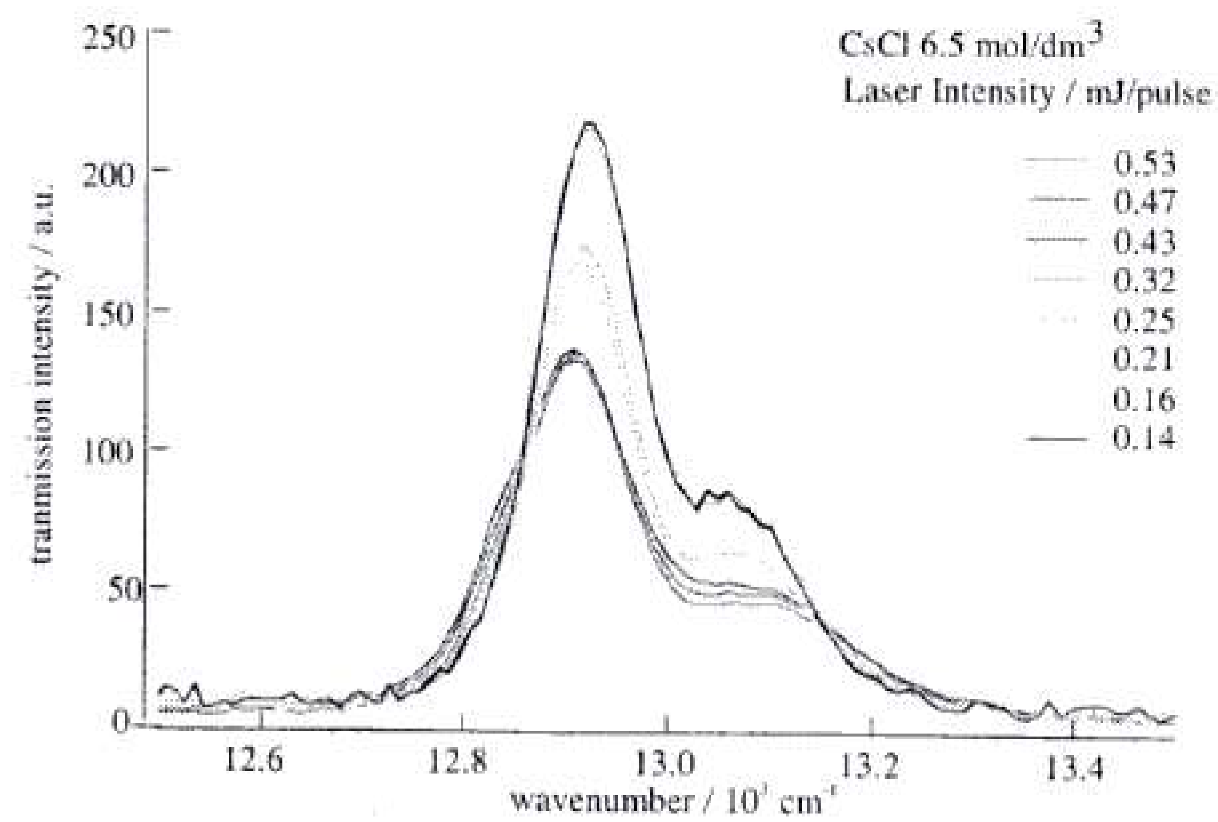
Experimental Setup for Transmitted-Laser Spectroscopy



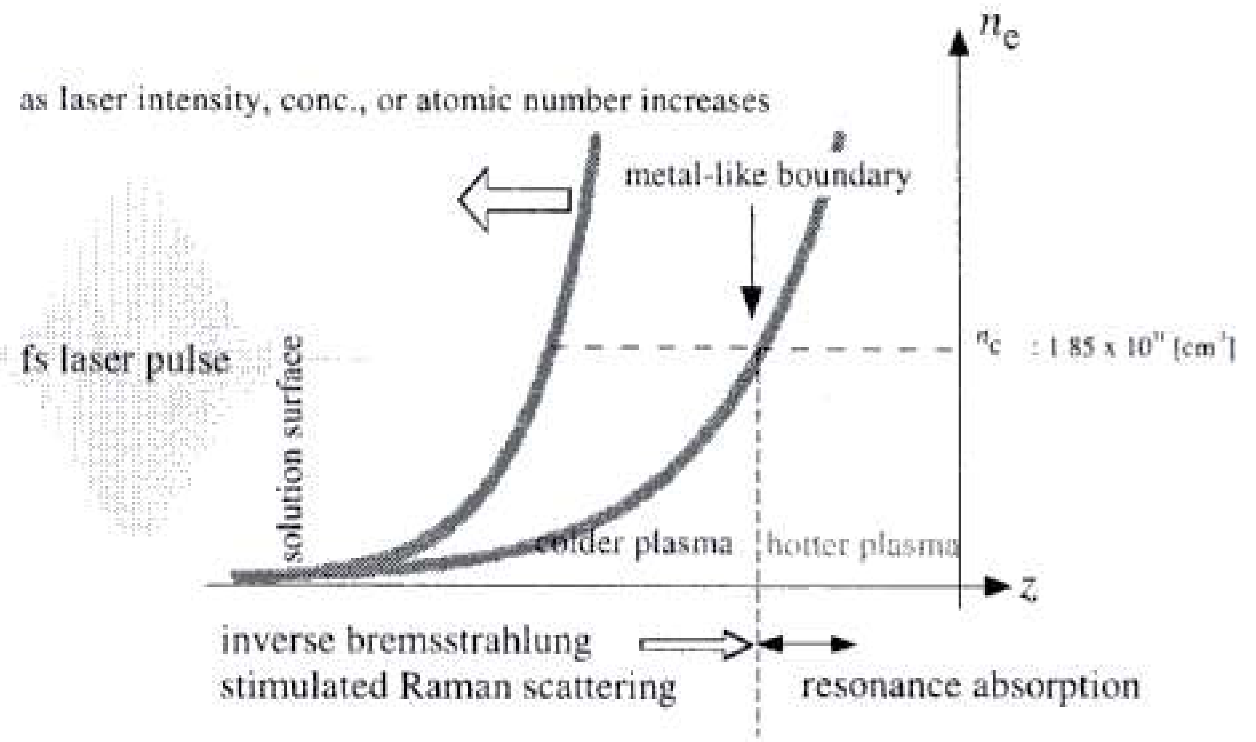
$$? ? = - (?_0/c) \int_0^L \frac{?n}{?t}(l)\, dl$$

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

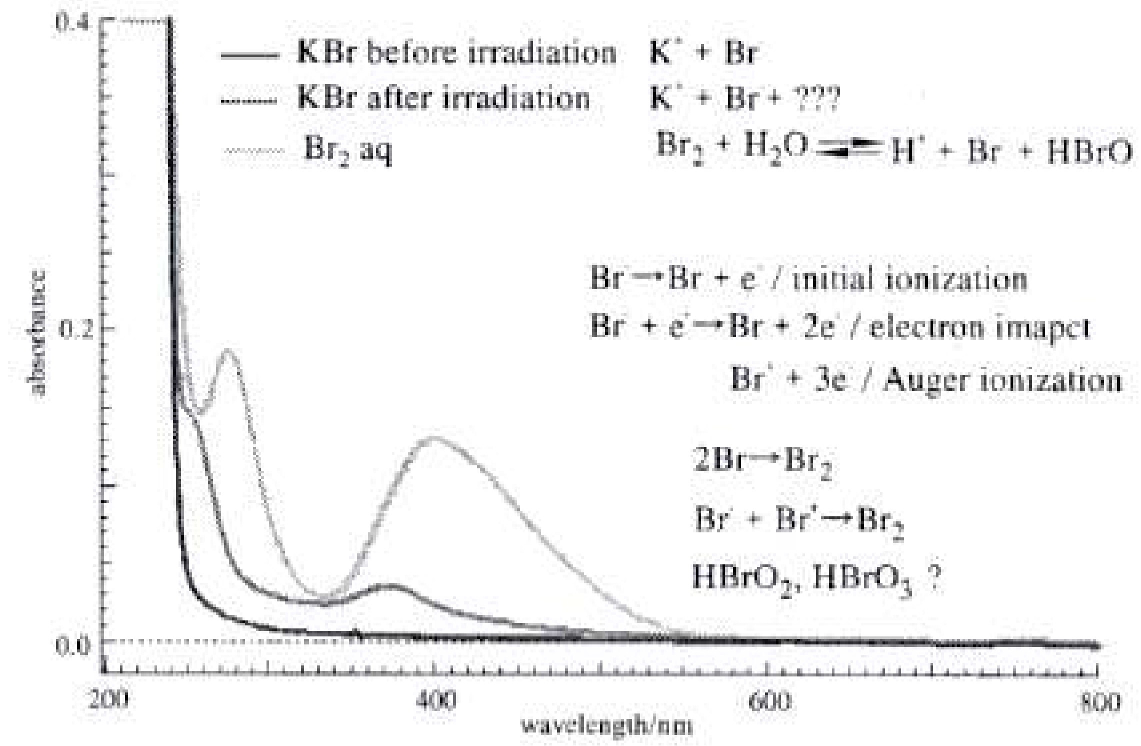
Frequency Blue Shift of Transmitted Laser Pulses



Conventional Laser Plasma Physics



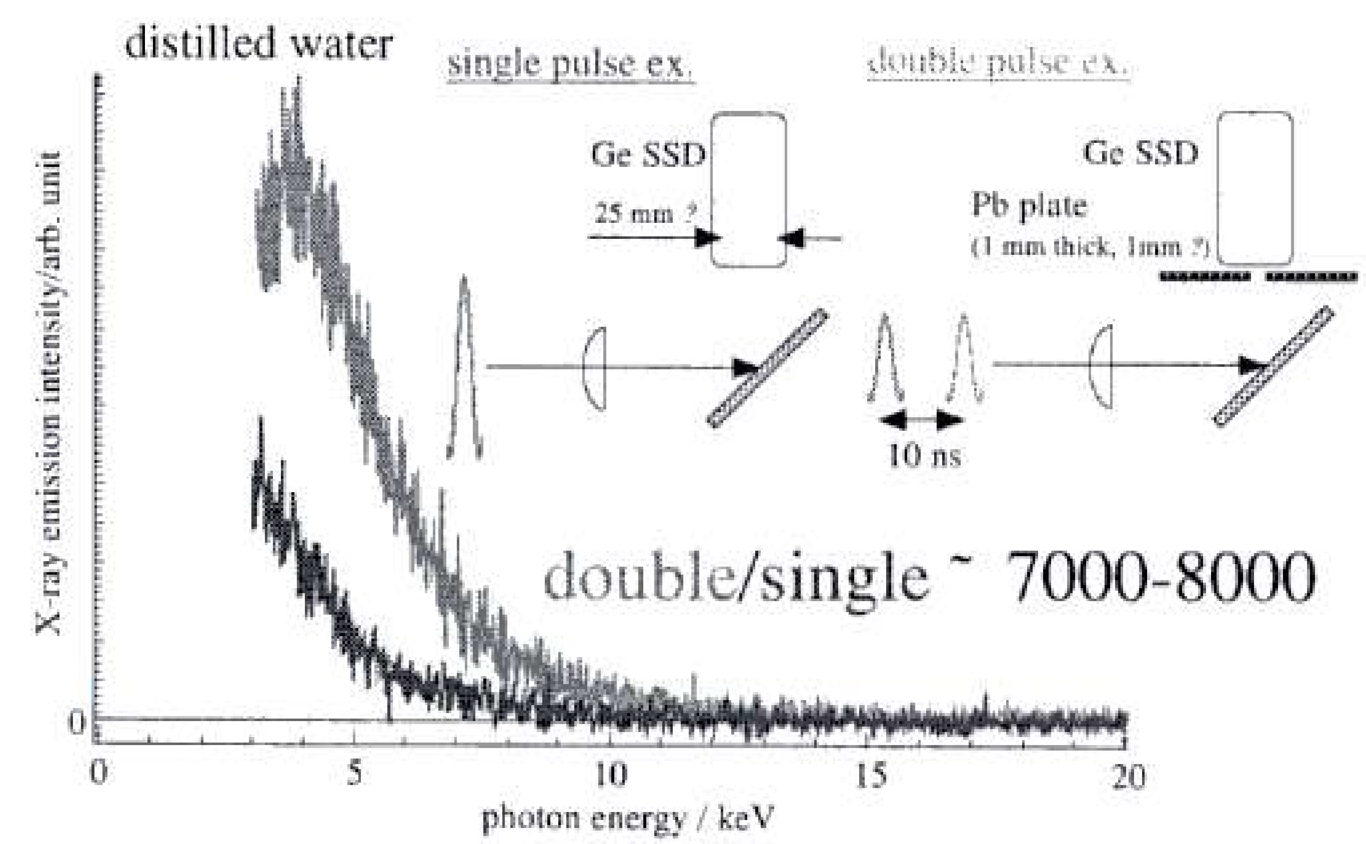
Chemical Reactions in PW Laser Field



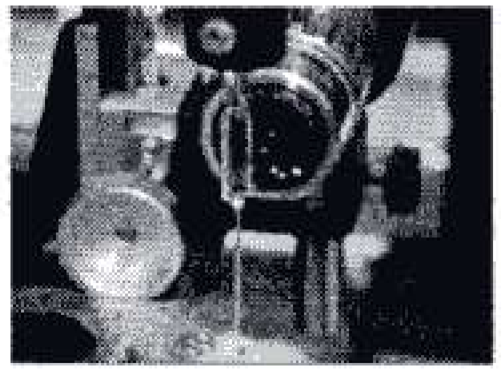
Information on X-ray Pulse Generation Dynamics is Needed.

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

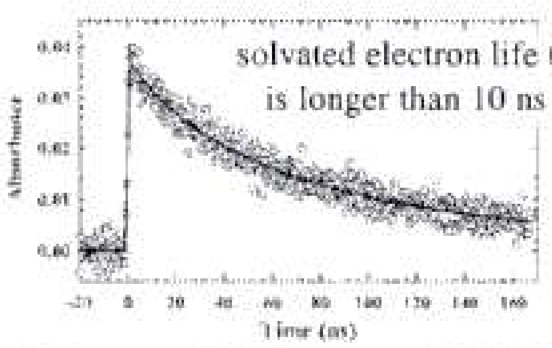
Double Pulse Excitation / X-ray Intensity Enhancement



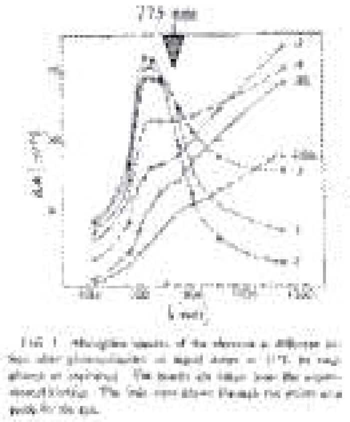
Double Pulse Excitation / Discussion



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



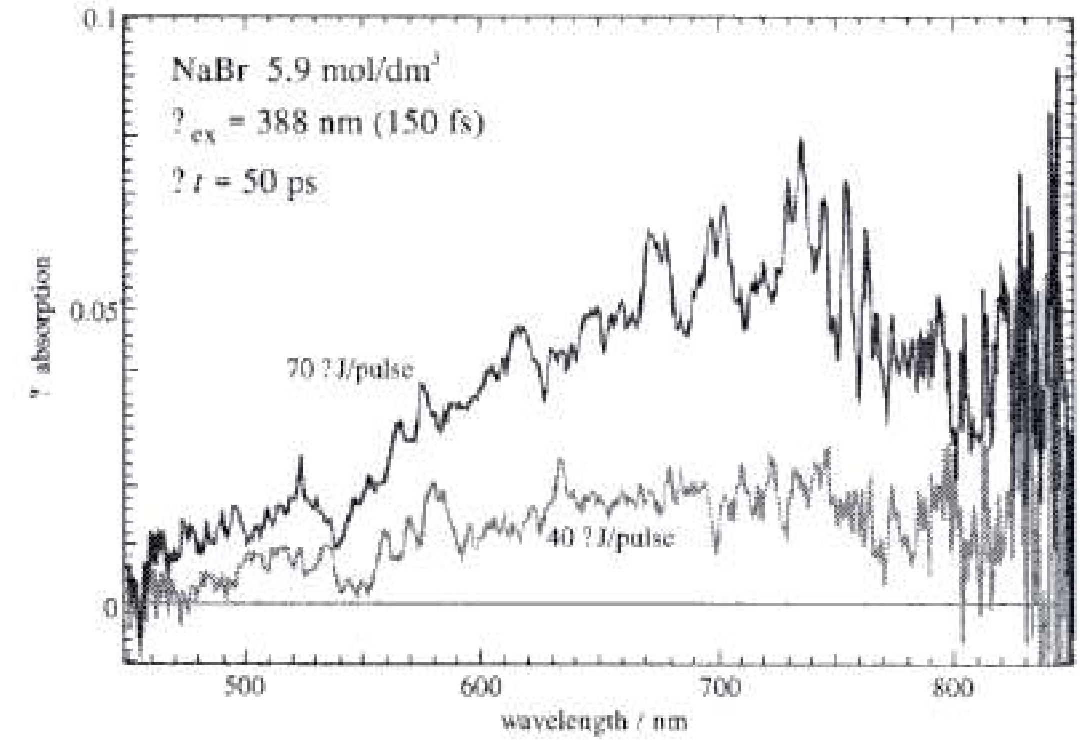
S. Pommeret, *et al.*, *Res. Chem. Intermed.* 27, 901, 2001



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

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

Solved Electrons / Time-resolved Absorption Spectroscopy



Possible Mechanisms for X-ray Pulse Generation

$n_e \geqq n_c = 1.85\times10^{21}$ [cm^{-3}] @ 775 nm