

EUV Source Fundamental Data Requirements

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Presentation Outline

- EUV Source Fundamental Data Working Group's Mission and Membership.
- Overview of Data Types Needed for Modeling.
- Status for Xenon.
- Benchmarking model output spectra.
- Summary/conclusion.

EUV Source Fundamental Data Working Group

- Evaluate the data needs of the source modeling community.
- Review and report on available data.
- Provide a central point-of-contact to coordinate sharing of unpublished data that may benefit the entire community.
- Generate white paper.

Fundamental Data Working Group

Members

John Gillaspay (NIST), chair

Vivek Bakshi, co-chair, ISMT Source Project Leader

Howard Milchberg (University of Maryland)

Ahmed Hassanein (Argonne National Laboratory)

Martin Laming (Naval Research Laboratory)

Yong-Ki Kim (NIST)

Konstantin Koshelev (Institute of Spectroscopy, Troitsk)

Gerry O'Sullivan (University College, Dublin)

Roberto Mancini (University of Nevada, Reno)

Martin Richardson (University of Central Florida)

Bryan Rice (Intel)

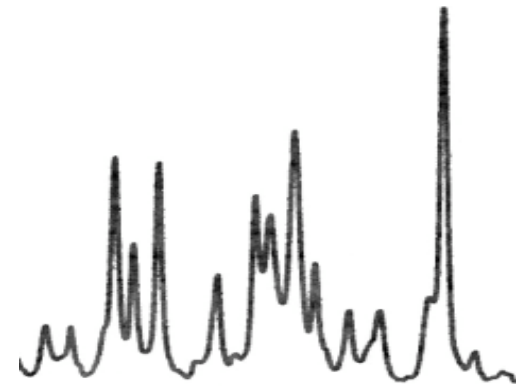
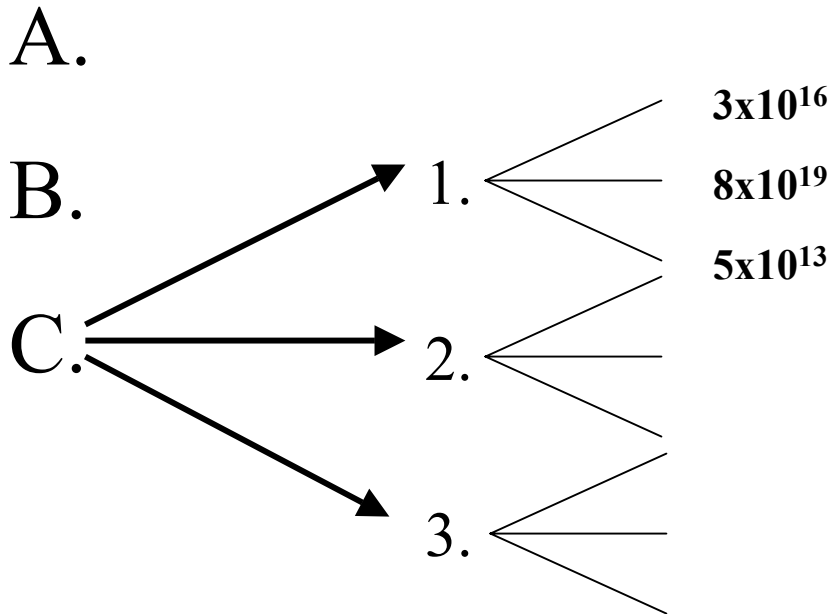
Jonathan Cobb (Motorola)

Martin Schmidt, (CEA Saclay)

Overview of Data Types

Type I
Input
(numbers)

Type II
Output
(benchmark spectra)



Specification of type I data:

A. Species (atomic number, Z):

The Working Group has focused on Xenon, but we are starting to consider Tin as well.

B. Charge State (q):

EUV emission at 13.5 nm in Xe is from $q=10+$. To accurately model this, ion data is needed for approximately $q=1-18$ (particularly $>q=6+$).

C. Data category:

1. Transition energies (wavelengths).
2. Ionization energies.
3. Cross sections (next page).

Types of Cross Sections:

Ionization

Electron Impact Ionization

Photoionization



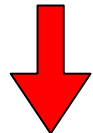
Recombination

3-body: $Xe(q)+e+e \rightarrow Xe(q-1)+e$

2-body (DR resonance): $Xe(q)+e \rightarrow Xe^*(q-1)$

Radiative Recombination
and its inverse: autoionization

Charge exchange (ion-neutral, ion-ion)

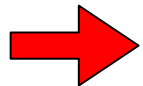


Excitation/Relaxation

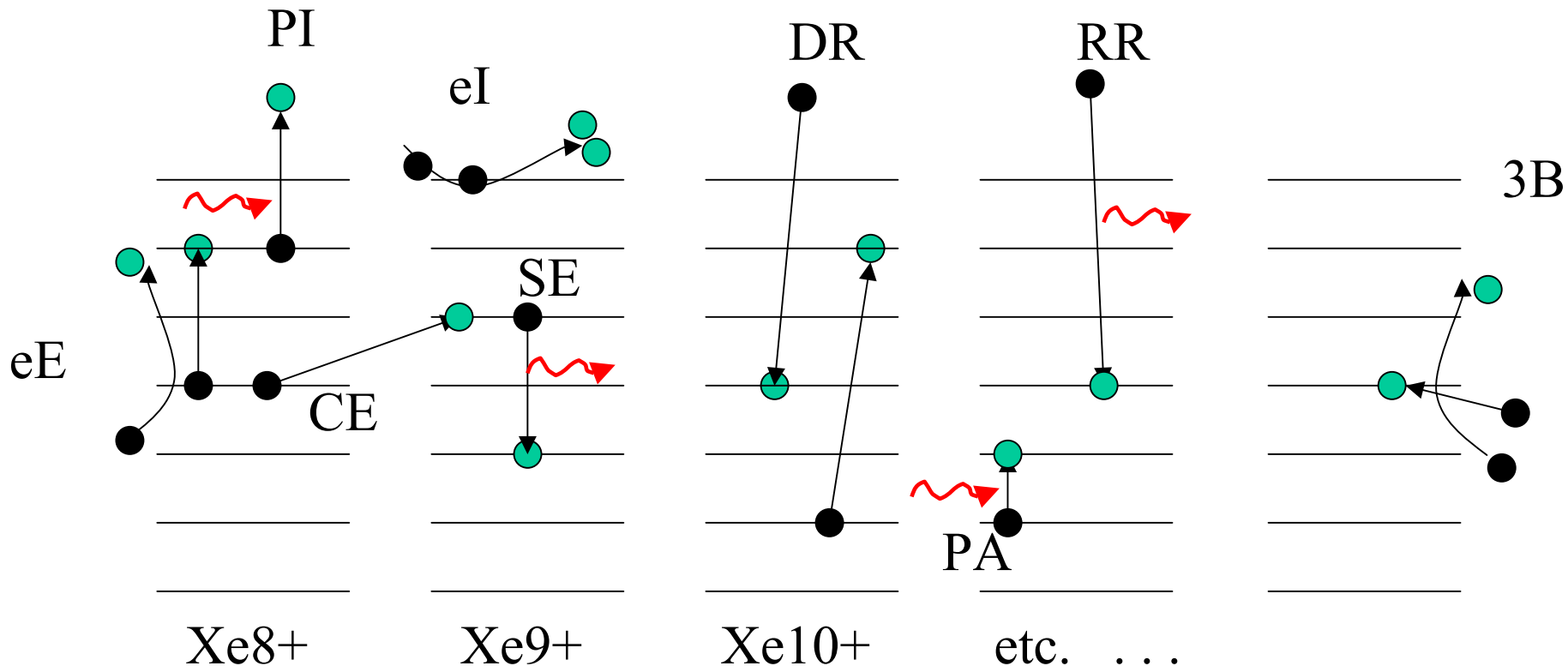
Spontaneous Emission (lifetimes or A-values)

Electron impact excitation/de-excitation

Photoabsorption (optical thickness issues)



Types of Cross Sections:



All of these TYPES of cross sections are required for EACH q .

Each TYPE may encompass 100's or even 1000's of CURVES of numbers corresponding to the many atomic LEVELS.

The data space rapidly expands: $2 \times 10 \times 100 \times 12 \times 24 > 500,000$

Status:

Many atomic and plasma data bases are available,

Many of which are listed on the Plasma Gate web site:

<http://plasma-gate.weizmann.ac.il/DBfAPP.html>

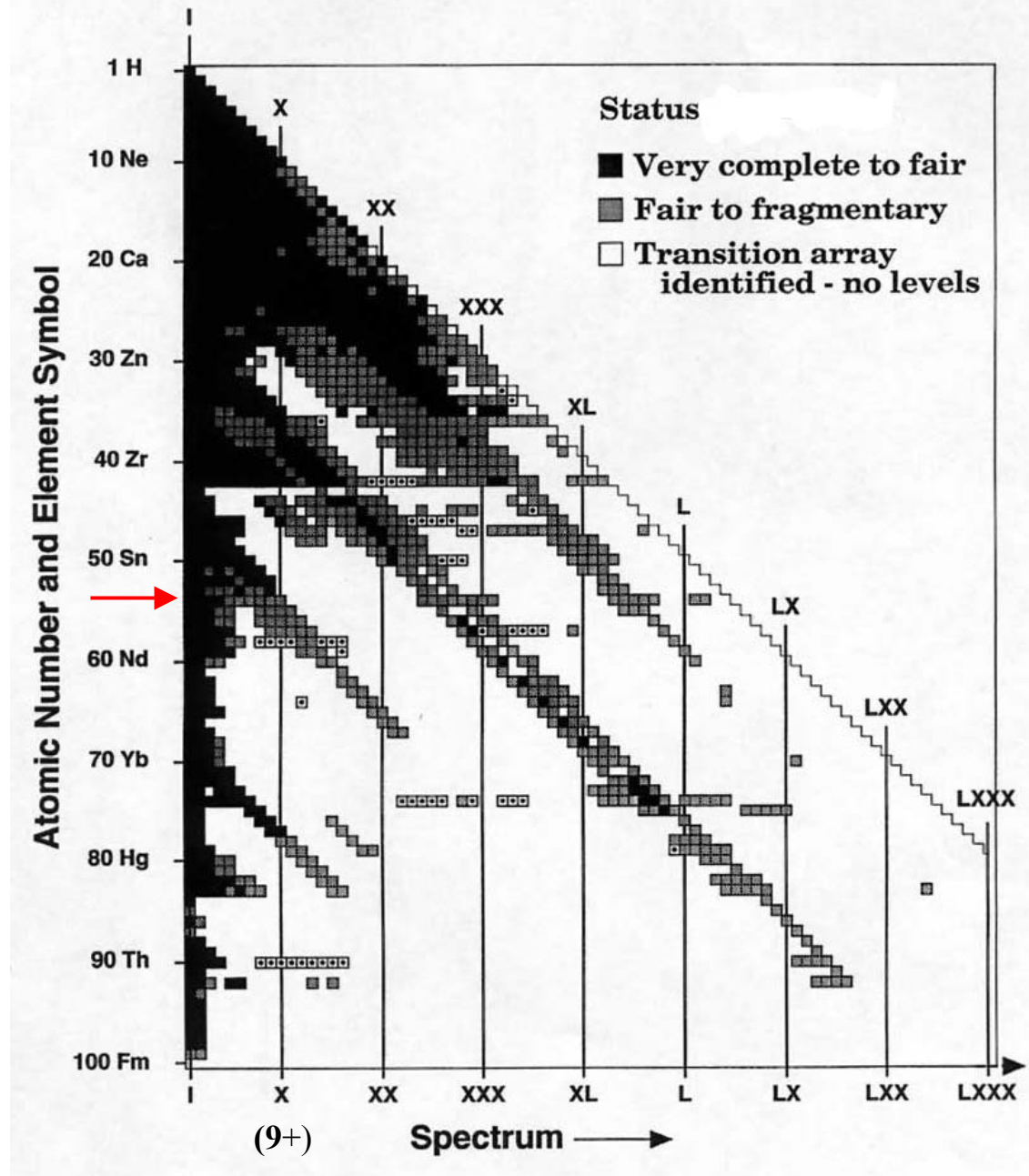
The databases tend to be missing what is needed for EUVL.

High charge states, in particular, are difficult to come by, except for species like Iron, which have been heavily studied under NASA funding.

Status:

For Xenon, published data is generally missing above charge states of 7-9.

Not only for spectral data (right), but also collision cross sections.

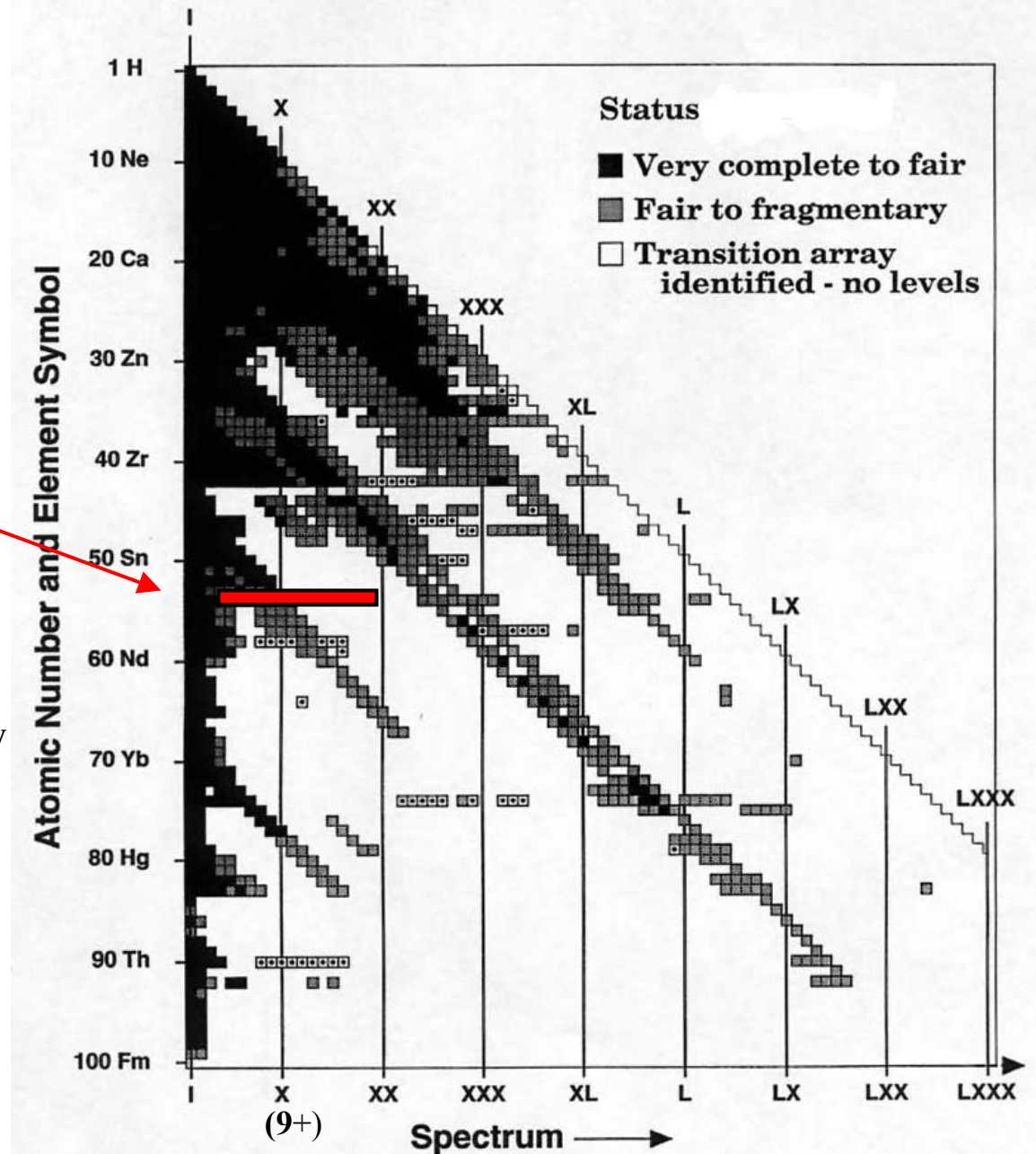


Status:

NIST Xe compilation
(preprint available
through ISMT).

Published wavelengths and energy
levels (1961-2002).

14 references to Xe VII (Xe6+)
14 references to Xe VIII (Xe7+)
10 references to Xe IX (Xe8+).
3 references to Xe X (Xe9+).
1 reference to XeXVIII (Xe17+).
2 references to Xe XIX (Xe18+).

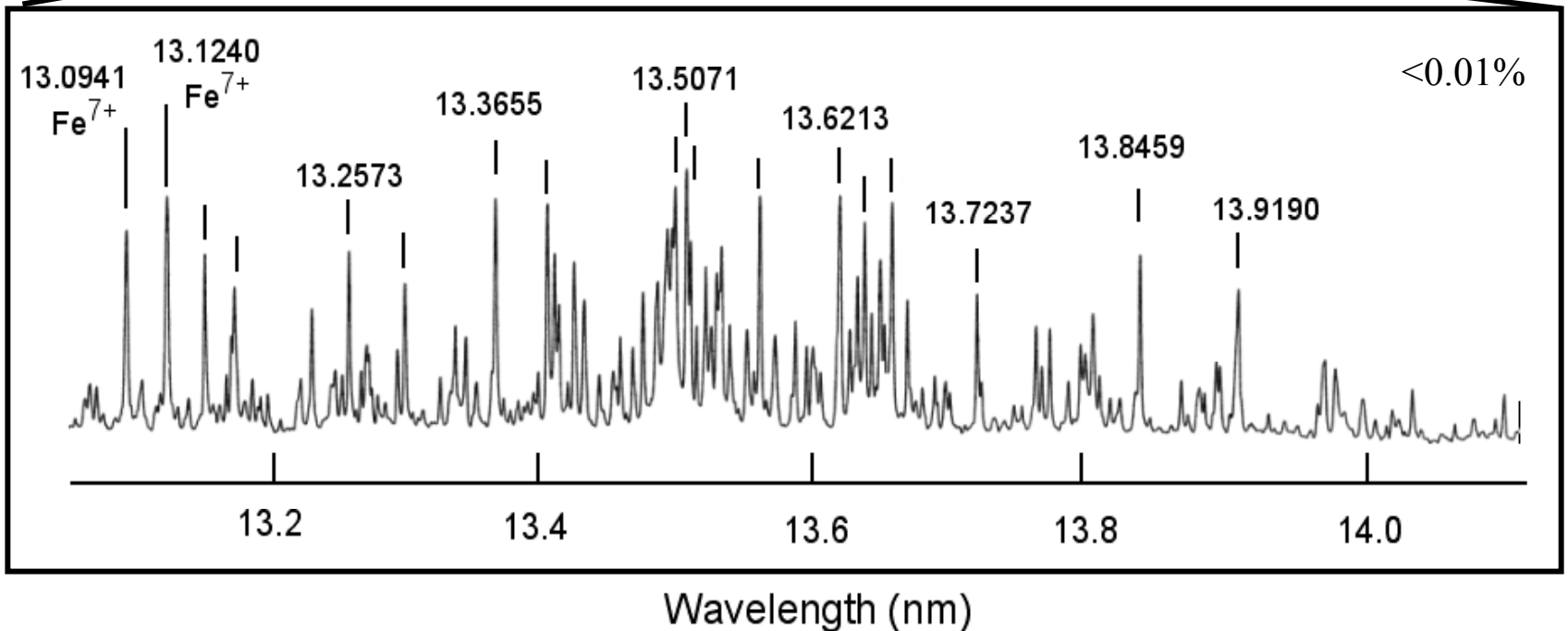
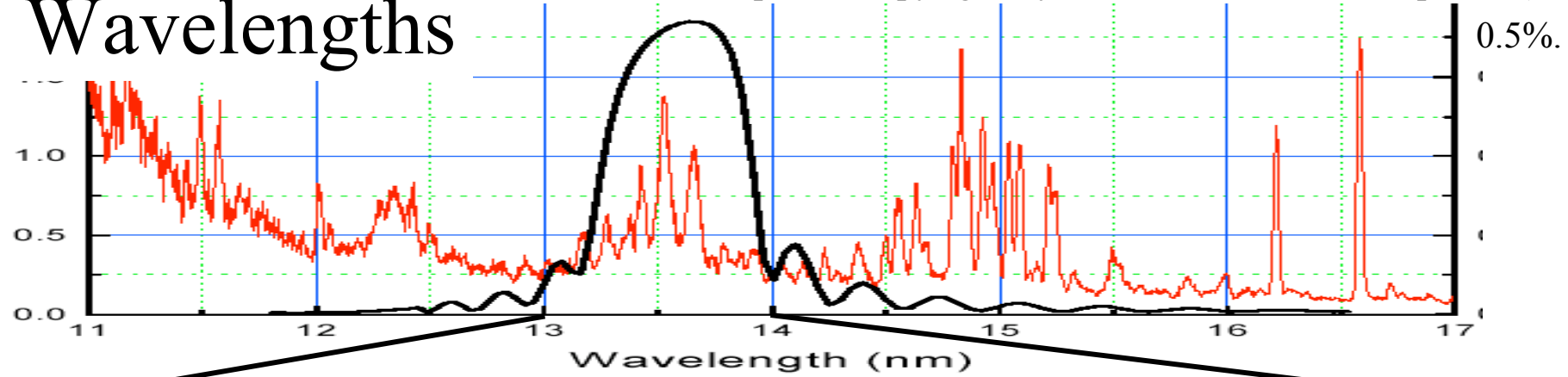


Status (unpublished):

1. Wavelengths are needed very accurately to resolve the structure of the spectrum, and also to test the accuracy of wavefunctions used in calculating cross sections (direct measurements of cross sections are difficult and time-consuming).

1. Wavelengths

Top data: copyright Cymer, 1st EUVL workshop, 2002).



Bottom data: new ultrahigh resolution spectra from NIST 10.7 m spectrometer. Churilov, Joshi, and Reader, preprint available through ISMT (2003).

2. Ionization Energies: known to at least 3%.

Charge	# of e-	Roman	Config	Term	EBIT	SCDF	SC-EBIT	Literature	
0	54	I	5p6	1S0	11.0	11.22673	0.22673	12.12984	} Agree to <3%
1	53	II	5p5	2P3/2	20.1	19.85394	-0.24606	20.97502	
2	52	III	5p4	3P2	30.1	29.60376	-0.49624	31.04564	
3	51	IV	5p3	4S3/2	40.7	41.65659	0.95659	40.91478	
4	50	V	5p2	3P0	53.9	53.87642	-0.02358	54.14389	
5	49	VI	5p	2P1/2	65.9	65.71570	-0.1843	66.7030	
6	48	VII	5s2	1S0	92.6	89.61138	-2.98862	91.59952	
7	47	VIII	5s	2S1/2	106.7	104.1730	-2.52699	105.9761	
8	46	IX	4d10	1S0	180.4	178.1859	-2.21412	179.8391	
9	45	X	4d9	2D5/2	205.7	201.6382	-4.06176		
10	44	XI	4d8	3F4	231.7	227.5624	-4.13756		
11	43	XII	4d7	4F9/2	258.5	254.6778	-3.82221		
12	42	XIII	4d6	5D4	286.1	280.6667	-5.43335		
13	41	XIV	4d5	6S5/2	314.3	314.2833	-0.01668		
14	40	XV	4d4	5D0	346.0	343.5413	-2.45869		
15	39	XVI	4d3	4F3/2	375.8	373.1942	-2.60579		
16	38	XVII	4d2	3F2	406.2	404.2271	-1.97295		
17	37	XVIII	4d	2D3/2	437.2	433.7355	-3.46445		
18	36	XIX	4p6	1S0	553.7	549.7384	-3.96157		
25									[at high q, agree with literature to <<1%]
26									

NIST, unpublished, Y.-K. Kim, 2003

Request: if anyone wants more accurate values, they can be generated (with considerable effort)--please notify me before the end of the conference.

3. Cross sections:

Difficult and time-consuming to measure. In most cases, will have to rely on calculations. Accuracy of 5-20% is expected to be adequate (best guess).

How difficult are they to calculate?

Number of
continuum
electrons:

Spontaneous emission--should be easy (10-15%).

0

Electron impact excitation--harder .

1

Electron impact ionization--harder still.

2

Dielectronic recombination--even harder (resonant).

Modelers should systematically vary specific input data by factor of two, and check variation in output, in order to determine most critically needed data.

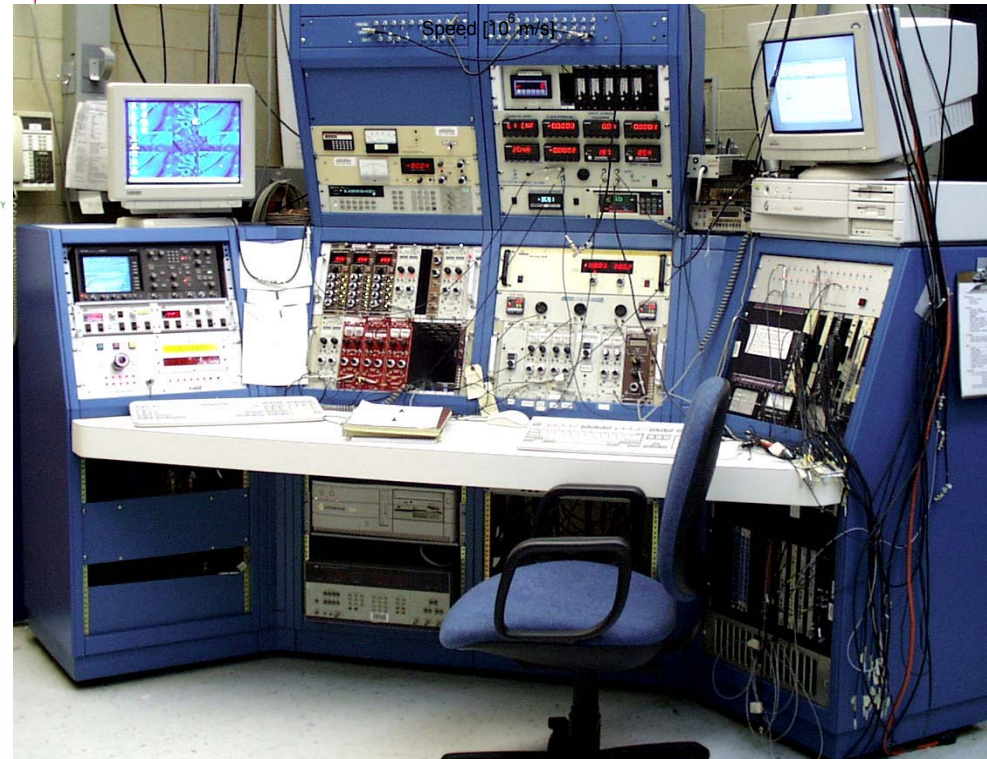
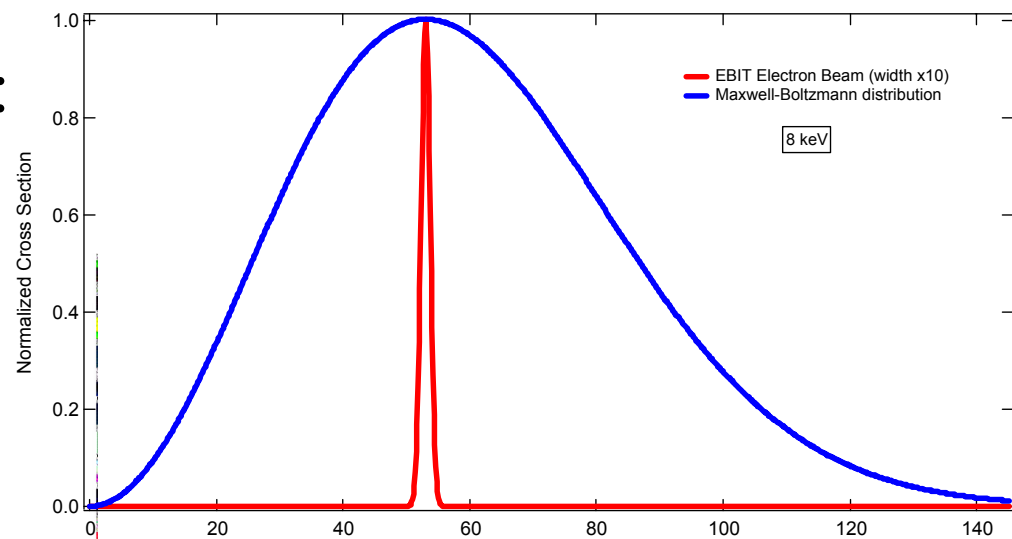
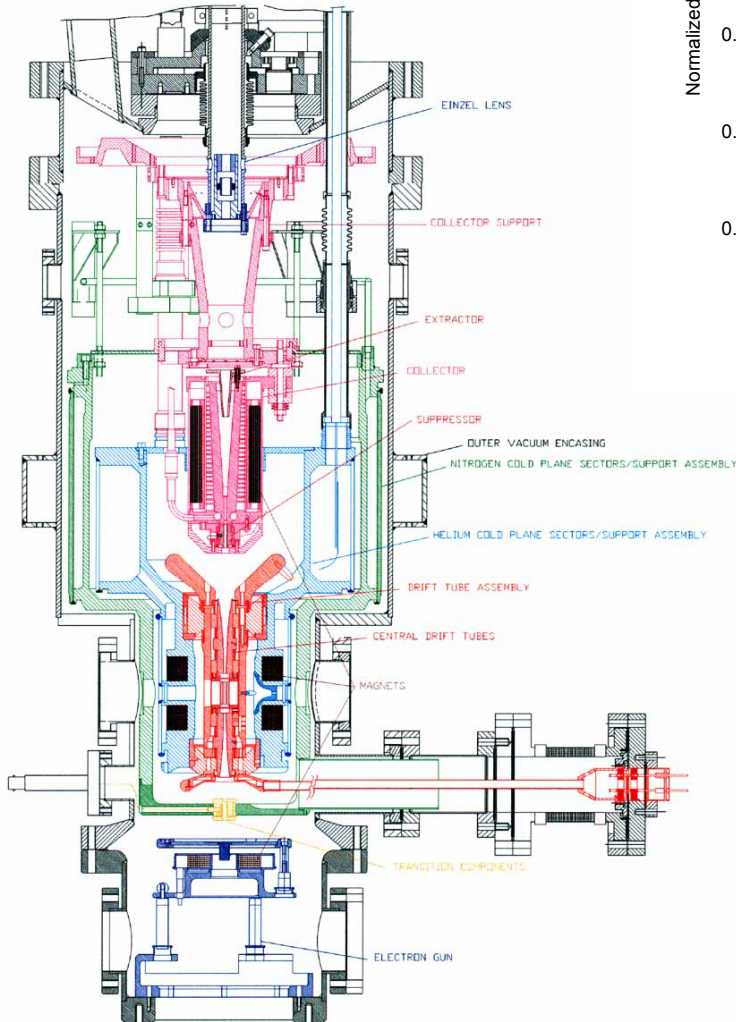
Type II benchmark data:

It is important to test the model on well-defined and well-characterized plasmas, over a wide range of parameter space, in addition to actual EUVL sources.

Anecdote (models that can be “adjusted to fit” don’t inspire confidence in understanding).

Benchmarking with EBIT:

Underway at NIST in connection with Roberto Mancini's modeling at UNR.



A few important side-points that emerged in the FDWG :

Coupling of atomic physics codes to hydrodynamics codes is a key area of concern. (What the model includes is at least as important as the quality of the atomic input data).

Need for modeling workshop?

Metastable states may shift the charge state spectrum to higher values than otherwise expected (easier to ionize from metastable level) Peter Venzek (Motorola) and Y.-K. Kim (NIST) have been through this before in the context of modeling etching plasmas.

Optical thickness issues are important, and require more attention by modelers.

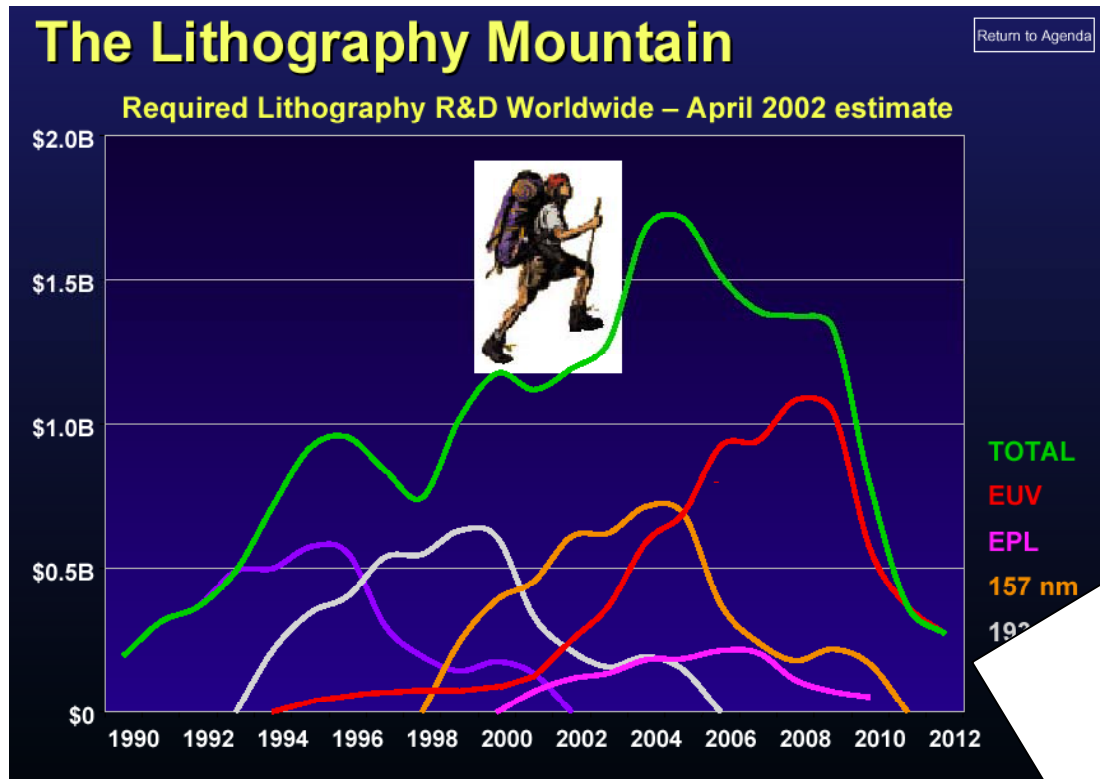
Summary

At least three types of work are needed:

1. Benchmark input data (test the data matrix).
2. Determine sensitivity of model to input data variation.
3. Benchmark output data (test the models).

(to be discussed in more detail in the breakout session)

We've only just begun.



Slide from Kevin Kemp,
1st EUVL symposium

Help Wanted

Send us data you can share (repository). john.gillaspy@nist.gov (301-975-3236)

Tell us your needs.

Help us benchmark and determine the sensitivity of models to variation in data
(there is room for a great deal of experimental and theoretical work).