CHEM 524 -- Course Outline (Sect. 2)

II. Light Sources (***Assignment*** ← alternate reading: Oriel hand out)

Conventional-incandescent and discharge → incoherent, all directions, no phase

vs. laser → coherent (frequency and phase well defined, directional)

All Electro-magnetic (E-M) radiation has orthogonal oscillating **E** and **B** fields

Figure S-0:

$\vec{E} = \vec{E}_0 \cos(kz - \omega t)$ $\vec{B} = \vec{B}_0 \cos(kz - \omega t)$ $\vec{B} \perp \vec{E}$ _(In − Phase)

A. Black body sources follow Planck result qualitatively (See table S-1)

TABLE 4-2

Common continuum sources

Type	Radiating material	Window or envelope material	Wavelength range	Approximate spectral radiance ($W\ cm^{-2}\ nm^{-1}\ sr^{-1}$)
Nernst glower	Rod of zirconia, yttria, or thoria at 1200–2000 K	None	0.4–20 μm	10^{-4}
Globar	Rod of silicon carbide at 1300–1500 K	None	1–40 μm	10^{-4}
Tungsten	Tungsten filament at 2000–3000 K	Glass	320–2500 nm	10^{-2}
Quartz-iodine ($T \leq 3600$ K)	Tungsten filament	Quartz	200–3000 nm	5×10^{-2}
Hydrogen or deuterium	Arc discharge in a few torr of H_2 or D_2	Quartz	160–370 nm	5×10^{-4}
Xenon arc	Arc discharge in >10 atm Xe	Quartz	200–1000 nm	10^{-1}

[a]Values are rough approximations at specific wavelengths: for Nernst glower and globar, λ = 10 μm; for tungsten, λ = 500 nm; for quartz-iodine with iodine stronger, λ = 400 nm; for H_2, λ = 250 nm; for Xe arc, λ = 500 nm (75-W lamp).

1. Black-body ideal: emission-absorption equilibrium, T-characterize, ref.standard

--source has constant energy density (ref. Text: Fig 4-1) See Figure S-1

Planck: ------ Stefan-Boltzmann: ---- Wien:

$E_\lambda^b = \frac{2hc^2}{\lambda^5}[e^{\frac{hc}{\lambda kT}} - 1]^{-1}$, $\int E d\lambda = \sigma T^4$, $\lambda_{max} = \frac{2.897 \times 10^6}{T}$

Higher temperature—maximum moves to vis-uv, intensity increase at all λ

Real sources -- correct for emissivity (ε≤1), transmittance (ref. Text: Fig 4-3)

$E_\lambda = \varepsilon(\lambda) T_e(\lambda) E_\lambda^b(T_e)$ → gray body at temp. T -- See Figure S-2, H-4

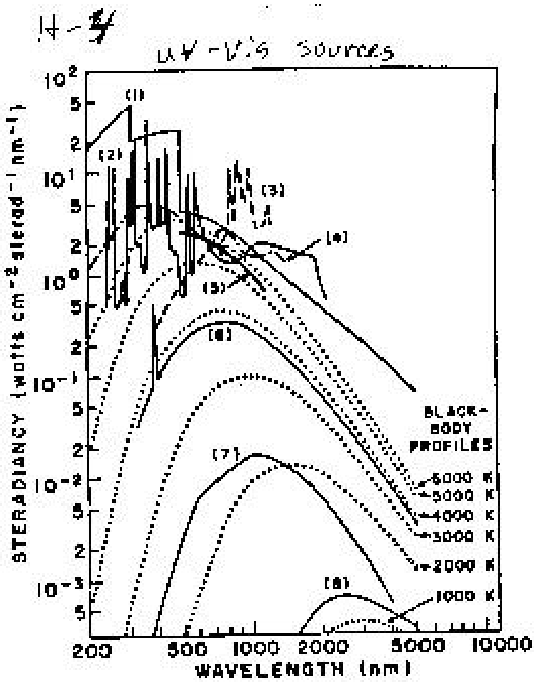


Fig. 10. Intensities of light sources for the visible and near visible: (1)—argon arc continuum (approximate calculation neglecting selfabsorption); (2)—mercury compact arc (PEK 110); (3)—xenon compact arc (PEK X75); (4)—Giannini vortex stabilized radiation source; (5)—high current carbon arc (brightness temperature 5800 K);[31] (6)—low current-carbon arc (brightness temperature 3900 K);[38] (7)—tungsten ribbon lamp (true temperature 2600 K, emissivities from De Vos[34] and Larrabee[34]); (8)—globar (color temperature 1175 K, emissivities from Silverman[40]).

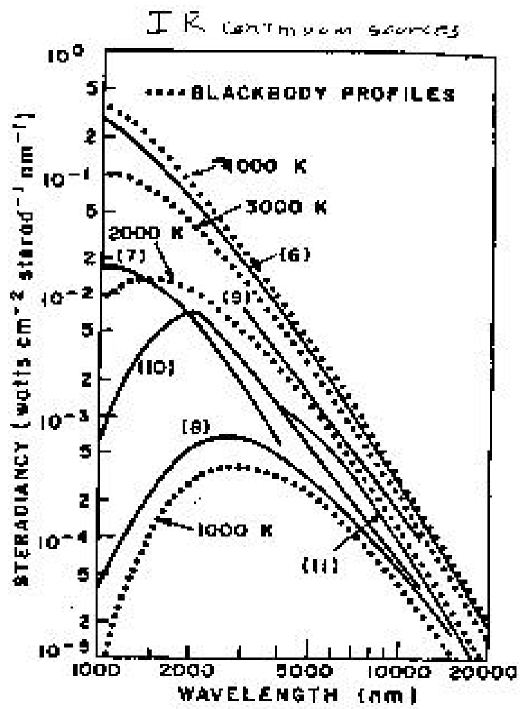
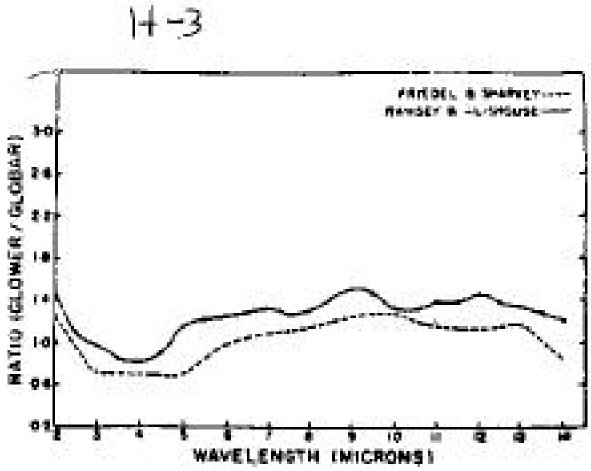


Fig. 11. Intensities of light sources for the ir. (1)-(8)—see Fig. 10; (9)—tungsten glower[34] (color temperature 2900 K); (10)—zirconium arc[48] (color temperature 2670 K); (11)—Nernst glower[41] (color temperature 1980 K; error in authors' figure corrected, see text).

[Figure 4 - discharge sources, uv-vis](#) [Figure 2 - incandescent, vis-IR sources](#)

2. Incandescent sources -- Continuum (in λ), continuous (in time),

- **EXAMPLES** (Text Table 4-2, Fig 4-5, 4-4) -
- Ceramic coated wire- -cheap, (low T_c~1000K)
- SiC Glower (Glowbar)- higher power, cooling required (T_c~1300-1500K)
- -- good for FTIR – cross-section like aperture (round)
- -- Compare to Nerst: Figure S-3,
- Nernst Glower- expensive, fragile, high temperature (T_c~1500→2000 K)
- --Lifetime inverse relate to TemperatueCompare to Glowbar: Figure S-3,
- --special circuit (negative coefficient of resistance),
- --good for dispersive, tall thin cross-section, high resolution
- C-Rod – cheap source, expensive housing, cooling, big power (KW), (T_c~2500 K)
- -- need inert atmosphere, good for IR with salt window (TAK group built)
- W-I lamp – inexpensive, wide variety of designs and powers (T_c~2500+ K)
- -- good for near IR, vis (typical for commercial vis. Absorption spectrometers)



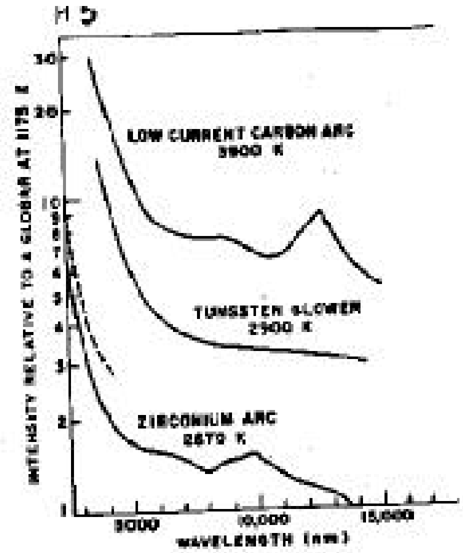


Fig. 5. Spectral irradiancies of the low-current carbon ... arc and tungsten glower relative to the gl... color temperatures are indicated.

Figure 3 - Nerst vs. Glowbar

Figure 5 - Discharge vs. Glowbar

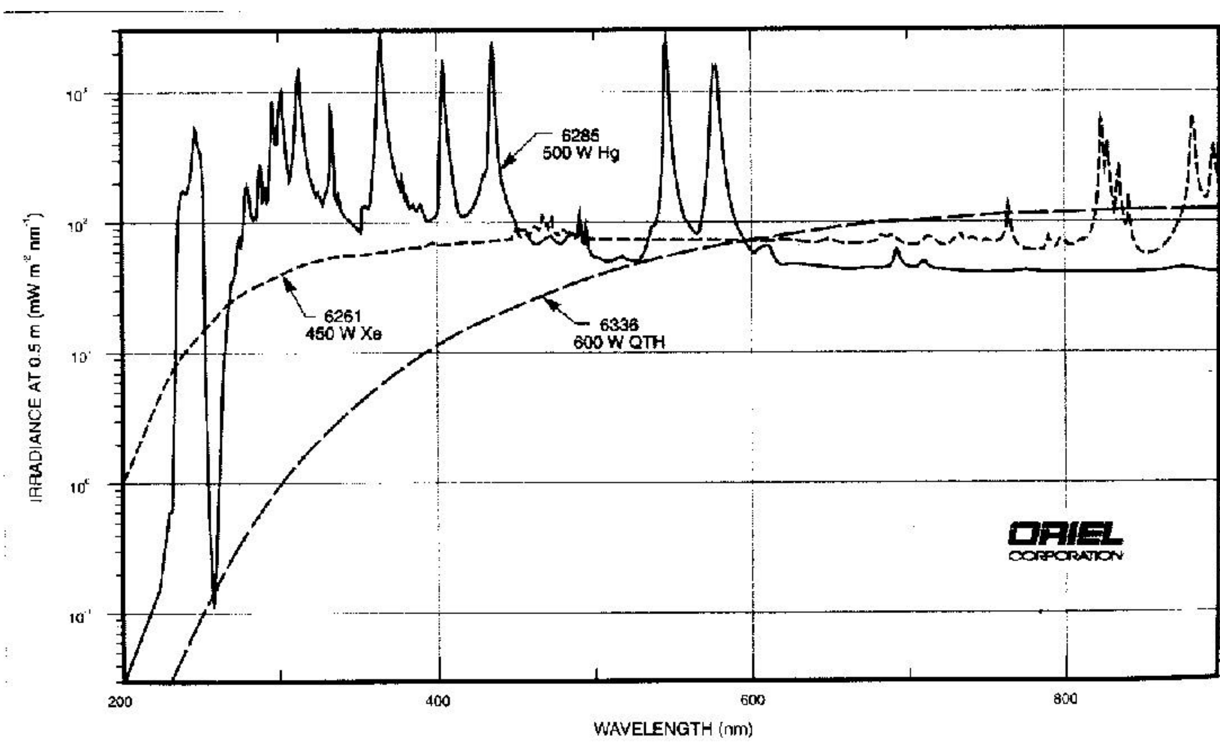


Fig. 10 200 to 900 nm spectral irradiance curves of quartz tungsten halogen and arc lamps.

B. Discharge sources , Compare to Black Body: again, also see, Figure S-4, Figure S-5,

1. Continuum—high pressure

- C-arc–old, stability problem, no window
- Xe-arc (include Xe-Hg and Hg) (Ar arc)– popular, quartz envelope (T~6000K)
- --Hg - makes intense uv, vis lines, good to stimulate fluorescence
- --Xe - common for CD, fluorescence, good near IR, but structured
- --Ar – good for vuv, not common
- H_2/D_2 discharge lamp –low power, good in uv, 370-180 (envelope) nm

2. Line sources– low pressure discharge- get atomic/ion lines

- Na – lamp $[\alpha]_D$ determination, ORD
- Hg – lamp–few uv vis lines (254nm max)–germacidal/fluorescence excite
- Hollow cathode–AA source, select analyte
- Electrodeless discharge–more intense–atomic emission

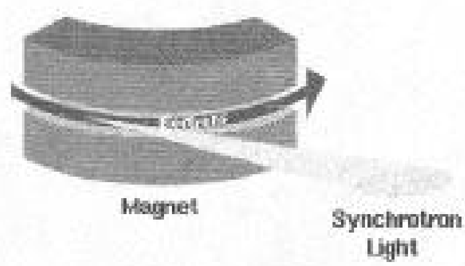
3. Standards

- Intensity -- W-I and others (NIST calibrate)
- Frequency -- atomic: Hg (simple), hollow cathode: Fe/Th (vis), Ne (red)

C. Synchrotron -- different mechanism

- experiment and operator must go to the source, especially inconvenient
- unique virtues: tunable, collimated, polarized, intense (high frequency pulses)
- – especially useful for uv, vuv , x-ray

How is synchrotron light produced?



When a charged particle travelling close to the speed of light is accelerated, it emits the broad spectrum of photons known as synchrotron light. At the SRS a beam of electrons is accelerated when it passes through a magnetic field, changing its path. The field is produced by sixteen huge 'dipole' electromagnets which constrain the beam to a roughly circular path 96 m around. Synchrotron light is emitted from all of these magnets and collected from 12 of them to feed experiments and test facilities. The light emerges like a searchlight in front of the emitting particle so it appears at a tangent to the bend. Three special magnets known as 'insertion devices' also produce light at the SRS.

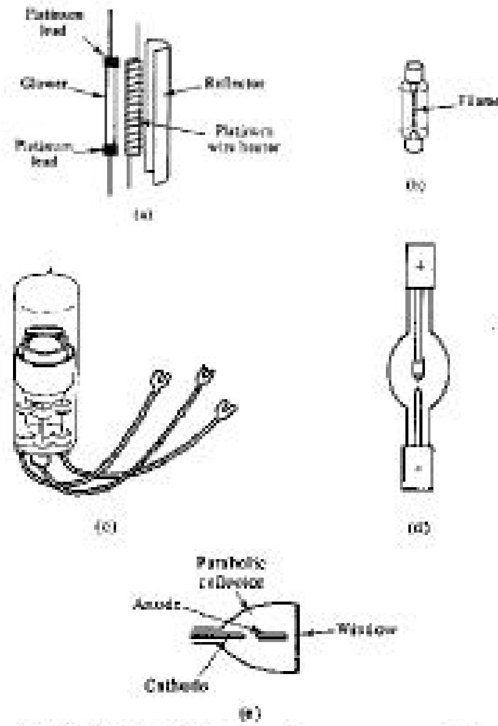


FIGURE 4-4 Typical continuum sources: (a) Nernst glower; (b) tungsten filament lamp; (c) D_2 lamp; (d) conventional Xe arc lamp; (e) EIMAC-type Xe arc lamp with parabolic reflector. The reader should consult Table 4-2 for further details.

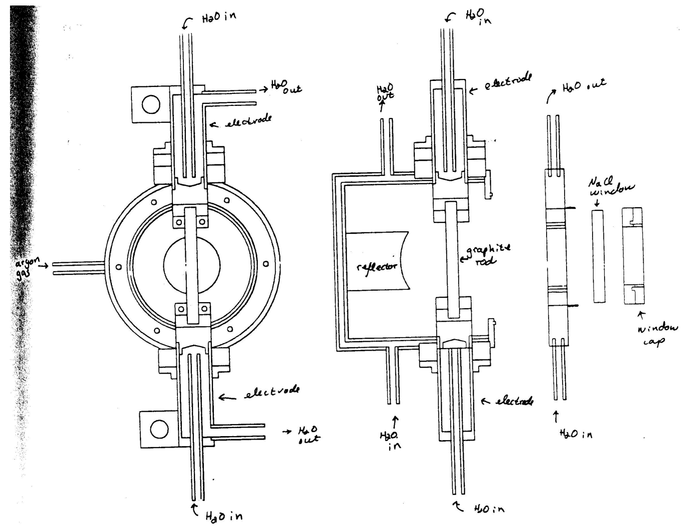
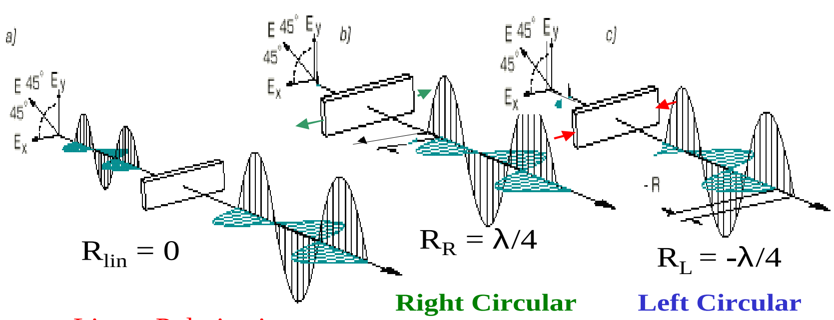


Figure 10. Schematic for carbon rod light source. The light source is purged with argon gas to prevent oxidation of the graphite rod. The light source is water cooled to prevent meltdown. Operating temperatures typically ~ 2500 K (1800 W).

Light Polarization

[courtesy Hinds Inc. brochure]



Linear Polarization
Preserved in isotropic medium,
but probes orientation of
chromophores in anisotropic sample

Right Circular Polarization

Left Circular Polarization

Phase retard orthogonal polarizations
forward or back with birefringent medium
Only maintained in isotropic sample

Web sites for lamps:

Physics Today Buyers Guide (L section-pick your lamp for vendors)
http://www.aip.org/ptbg/browseP.jsp?alpha=L

Oriel Corporation, Lamps section:
http://www.oriel.com/netcat/VolumeIII/Descrippage/lamps.htm

Hammamatsu Lamps:
http://www.hpk.co.jp/eng/main.html →follow Electron tube products to lamps

PTI fluorescence specialists:
http://www.pti-nj.com/obb.html

Eurosep supplier of lamps
http://www.eurosep.com/Dep_light/light4.htm

Perkin-Elmer Lamps (include CERMAX lamps, succeed EIMAC, under short arc Xe)
http://optoelectronics.perkinelmer.com/producttemplates/technology.asp?LevelId=14348&c=99&s=2&ss=4

Ushio America, large selection--go to Products, then Scientific-Medical
http://www.ushio.com/

Solar Light Co.
http://www.solar.com/sources.htm

Cairn Research
http://www.cairnweb.com/menus/menustub_product.html

Other Sites of possible interest:

Section from a related course, analytical chemistry (u.g.)
www.chem.queensu.ca /PROGRAMS/UG/Chem272/lectures/
Analytical encyclopedia and spectroscopy pages--on-line course in analytical chemistry
http://elchem.kaist.ac.kr/vt/index.htm
Spectrum page
http://elchem.kaist.ac.kr/vt/chem-ed/light/em-spec.htm