CHEM 524 - Course Outline (Sec.2) – 2011update

FOR A html VERSION OF 2005 NOTES , linked FIGURES CLICK HERE

II. Light Sources Chap 4 (*Assign* -- alternate reading: Oriel Technical notes)

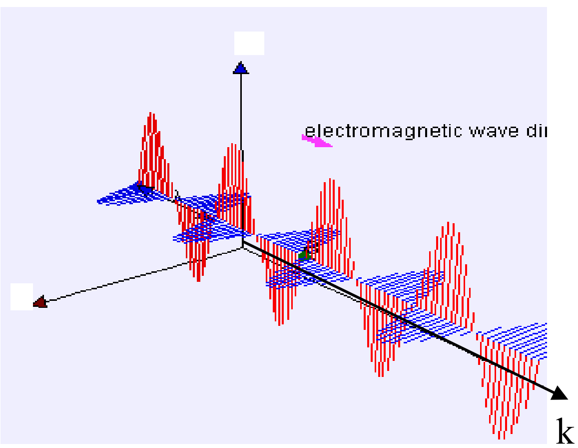
Conventional - incandescent and discharge
-- *incoherent*, emit in all directions, no phase coherence

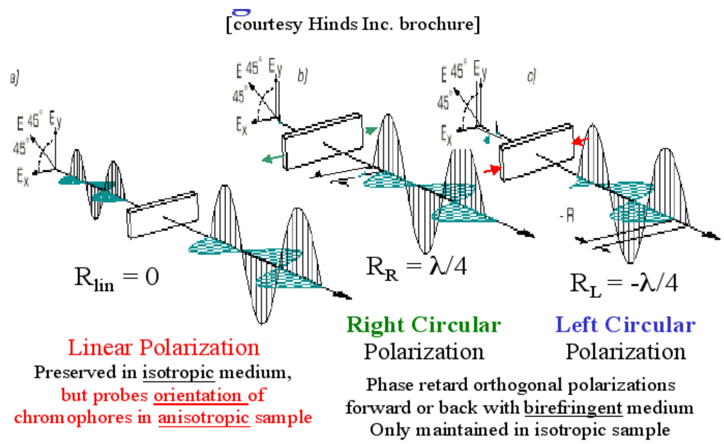
vs. **Laser** – *coherent* (frequency and phase well defined, directional)

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

$$\dot{E} = \dot{E}_0 \cos(kz - \omega t) \qquad \dot{B} = \dot{B}_0 \cos(kz - \omega t) \qquad \dot{B} \perp \dot{E} \quad \text{(In Phase)}$$

Polarization indicates orientation of **E** and **B** fields, $|k| = 2\pi/\lambda$ $\omega = 2\pi c/\lambda$ $\boldsymbol{k} \perp \boldsymbol{B} \perp \boldsymbol{E}$





A. Black body sources follow Planck qualitatively-examples (table 4-2)

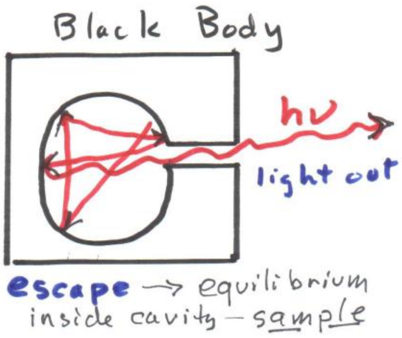
Type	Radiating material	Window or envelope material	Wavelength range	Approximate[a] spectral radiance ($W\ cm^{-2}\ nm^{-1}\ sr^{-1}$)
Nernst glower	Rod of zirconia, yttria, or thoria at 1200–2000 K	None	0.4–20 μm	10^{-4}
Globar	Rod of silicon carbide at 1300–1500 K	None	1–40 μm	10^{-4}
Tungsten	Tungsten filament at 2000–3000 K	Glass	320–2500 nm	10^{-2}
Quartz-iodine ($T \lesssim 3600$ 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	180–370 nm	5×10^{-3}
Xenon arc	Arc discharge in >10 atm Xe	Quartz	200–1000 nm	10^{-1}

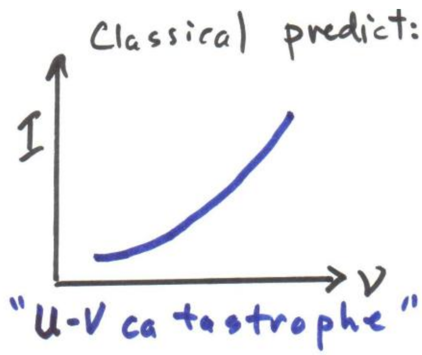
[a]Values are rough approximations at specific wavelengths: for Nernst glower and globar, λ = 10 μm; for tungsten, λ = 500 nm; for quartz-iodine with iodine scavenger, λ = 400 nm; for H_2, λ = 250 nm; for Xe arc, λ = 500 nm (75-W lamp).

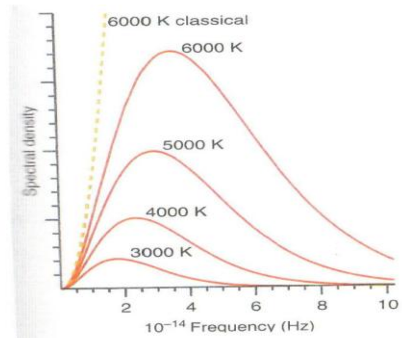
1. **Black-body ideal**: emission-absorption equilibrium,

T-characterizes shape, relative intensity, λ_{max}

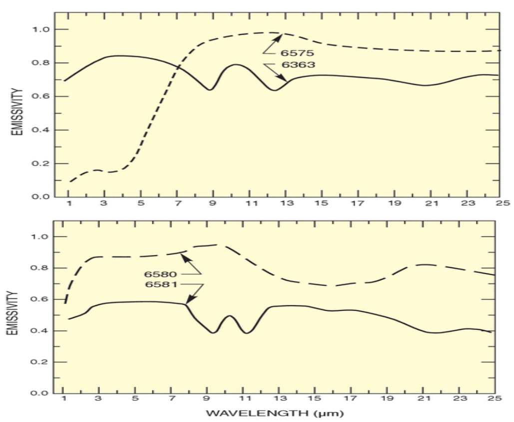
standard reference is a heated cavity whose emissivity is flat (ε~1)

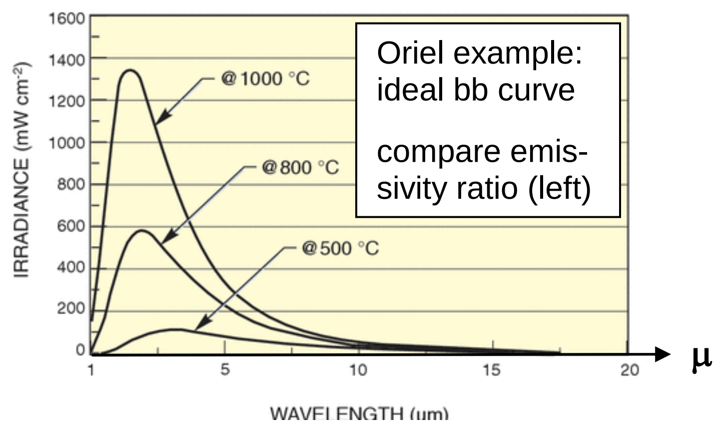


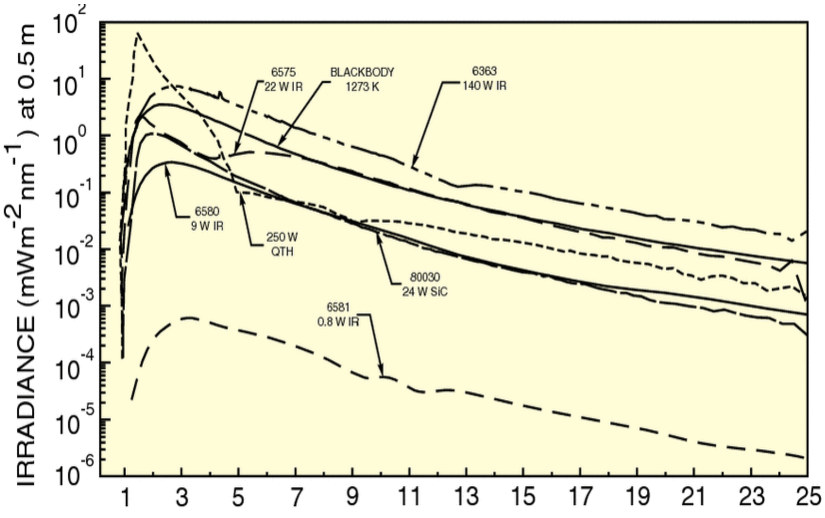


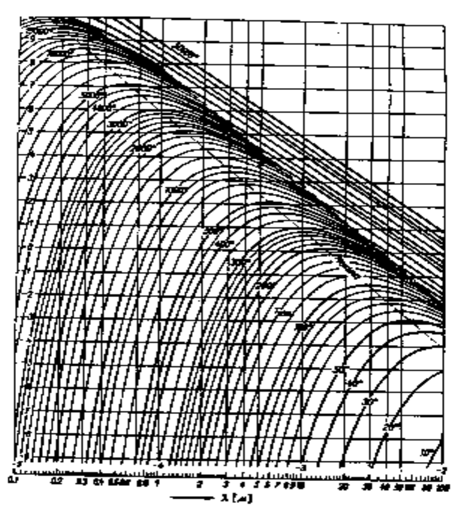


emissivity concept: ratio source radiance to bb at same T









Irradiance of several incandescent sources, compared to bb

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

--shifts intensity and frequency with increasing temperature

Planck (distribution): **Wien (λ max):** **Stefan-Boltzmann (integrated int.):**

$B = (2hc^2/\lambda^5)(e^{hc/\lambda kT} - 1)^{-1}$, $\lambda_{max} = (2.897 \times 10^6)/T$ (in nm), $\pi \int B d\lambda = \sigma T^4$

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

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

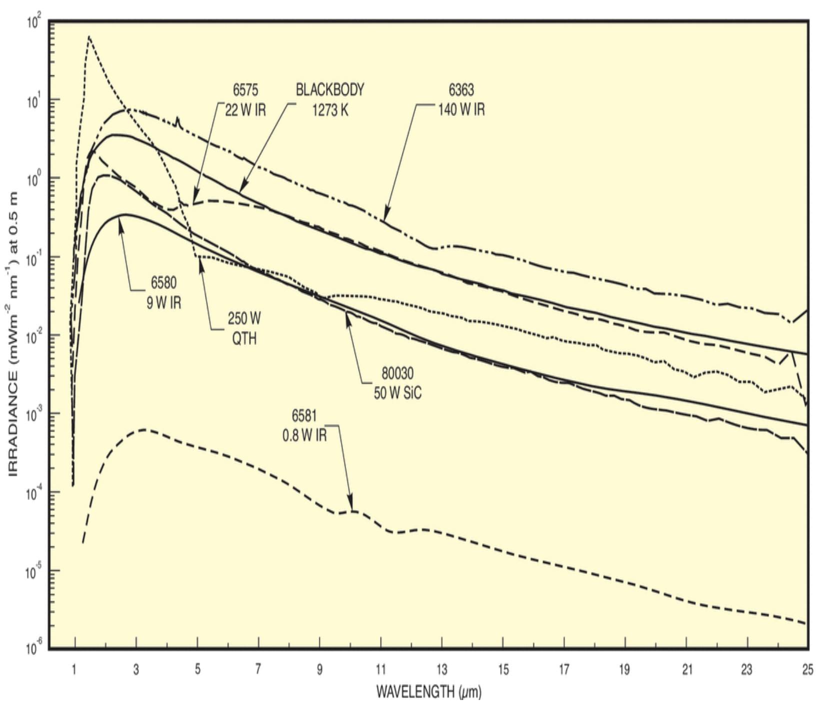
ε = Ratio radiance to black body, same temperature (often fit color temperature)

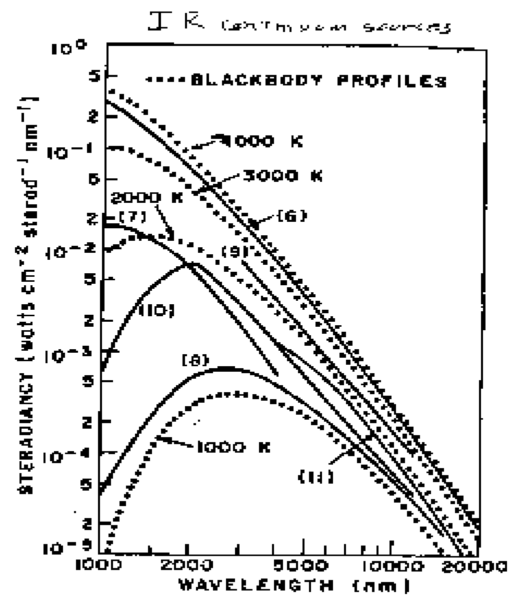
Compare ceramic sources (ceramic vs. IR emitter),

(ex. above top-left, Oriel Ceramic (6575) vs IR emitter (6363)-coated metal)

- gray body at temp. T_c correct for ε(λ) and T(λ)– $B_\lambda = \varepsilon(\lambda) T_\nu(\lambda) B_\lambda^b(T_c)$
- See : Figure 2 - incandescent, vis-IR sources, Figure 4 – discharge sources, uv-vis

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





Intensities of light sources for the ir. (1)–(8) [illegible] (9)—tungsten glower (color temperature 290[illegible]) [illegible]conium arc (color temperature 2670 K); 11)—[illegible] (color temperature 1980 K; error in authors' figure corrected, see text).

Note: (left) #s are various ceramic and metal glowers, lower power, QTH—quartz/halogen W lamp (higher temp), SiC like glowbar, blackbody is ideal

EXAMPLES (Text Table 4-2, Fig 4-5, 4-4) –

Ceramic coated wire-(Oriel models linked) -cheap, (low T_c~1000K)



Left: 6363, 6575, 6580 and 6581 Infrared Elements - Oriel, on right, SiC glowbars, surface igniter

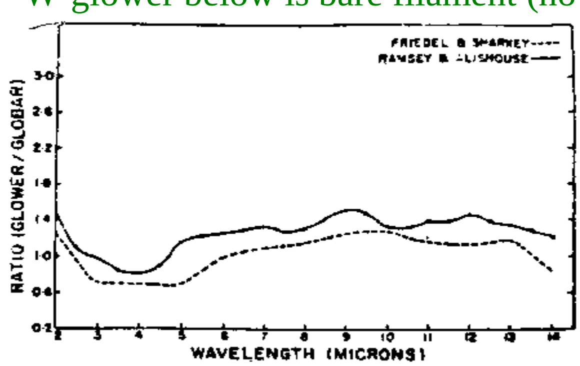
Model	Element Type	Voltage (V)	Operating Current (A)	Typical Power (W)	Nominal Radiating Area	Total Area	Color Temp (K)	Average Life	Price
6363	IR Emitter	12.0	12.0	~140	6.4 x 17.5 mm	6.4 x 104 mm	1000 - 1050	1 year	$232.00
6575	Ceramic Element	2.5 to 3.5	6.8 to 8.2	22	3 x 10 mm	3 x 15 mm	1600 - 2000	600 h	$556.00
6580	Low Cost Element	5.0	1.8	9	3.6 x 3.6 mm	7 x 3.7 mm	1100 - 1150	3 years	$284.00
6581	Miniature Element	8,0	0.1	0,8	100 µm dia.x 7 mm long	100 µm dia. x 7 mm long	≥1000	1 year	$362.00
80030	SiC Element	12.0	1.8 to 2.4	24	3.8 x 5 mm	3.8 x 12.7 mm	~1273	2000 h	$252.00

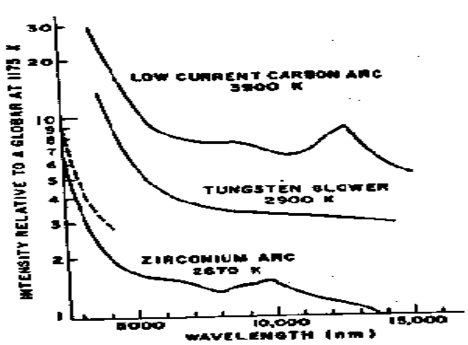
Classic (generic) IR models:

SiC Glower (Glowbar)- higher power (large size), cooling needed (T_c~13-1500K)

-- good for FTIR – cross-section like aperture (round-area important)

- Compare Nerst to Glowbar: SiC better ~4 µ, but worse at 5-14 µ,
  -- W-glower below is bare filament (no envelope), better than glowbar, esp. low λ



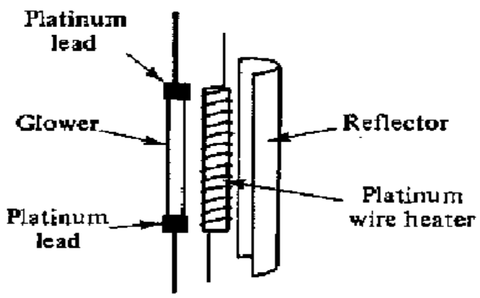


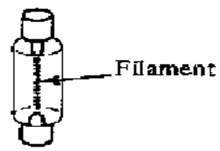
- ratio Nerst glower to SiC glowbar   ratio visible sources (W and arcs) to glowbar

Nernst Glower- expensive, fragile, difficult connect -- no longer commercial viable

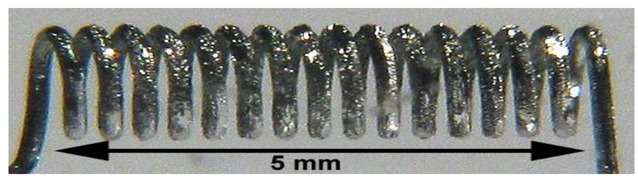
but can have high temperature (T_c~1500 – 2000+ K) but >2000 short life

- --Lifetime inverse relate to Temperature,
- Efficiency compare to Glowbar (see above):
- -- circuit (negative coefficient of resistance), heat to start conducting
- --fit high resolution dispersive, illuminate slit - *tall, thin cross-section*





(b)

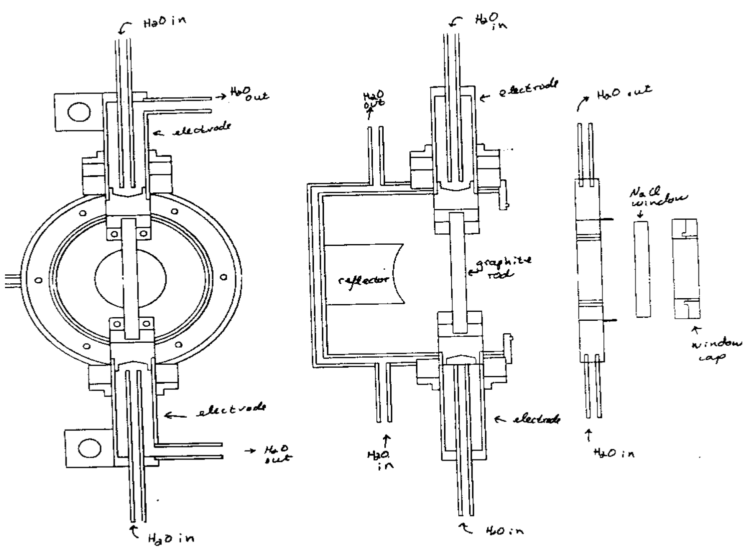


Nerst glower schematic and rod Quartz halogen –W filament coil, qtz envelop

C-Rod – cheap source, expensive housing, cooling, big power (KW),
and very high color T (T_c~2500 K)

- -- need inert atmosphere, good for IR with salt window (TAK group)

Front – electrodes up/down Side-explode frnt plate/window uv-vis source compare W (7), SiC(8)



'igure 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).

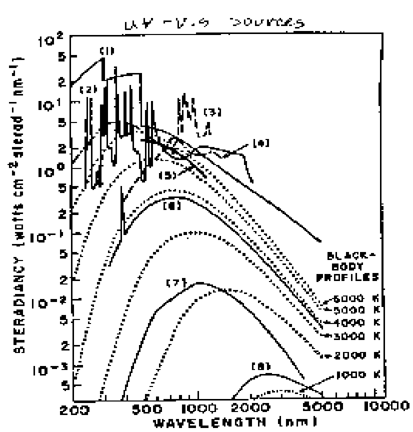
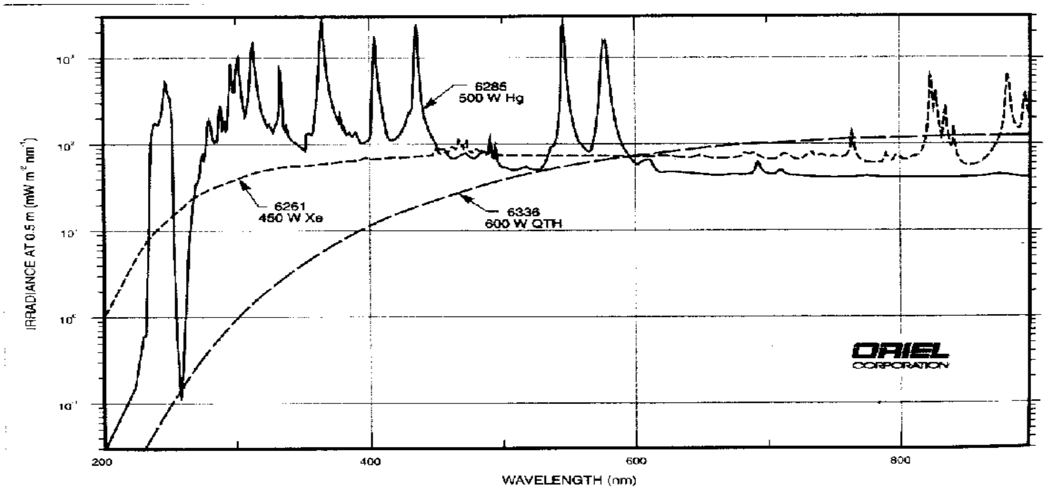


Fig. 10. Intensities of light sources for the visible and near visible: (1)—argon arc continuum (approximate calculation neglecting selfabsorption); (2)—mercury compact arc (PEK 110); (3)—xenon compact arc (PEK X75); (4)—Giannini vortex stabilized radiation source; (5)—high current carbon arc (brightness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

[W-I lamp](#) – inexpensive, wide variety of designs and powers (T_c~3000 K) (above)

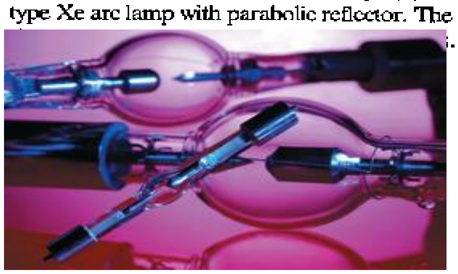
- -- good - near IR, vis (typical commercial visible absorp. spectrometers)
- --compare to black body and SiC (Oriel catalog) [radiance 7 vs 8 above]
- --compare to discharge lamps, below

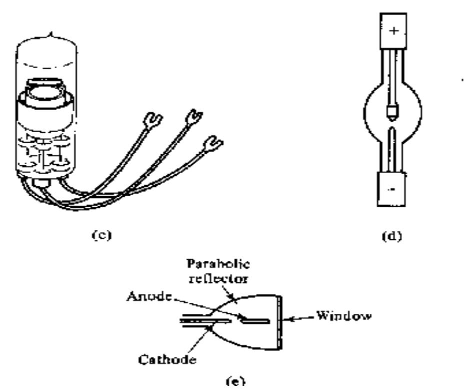


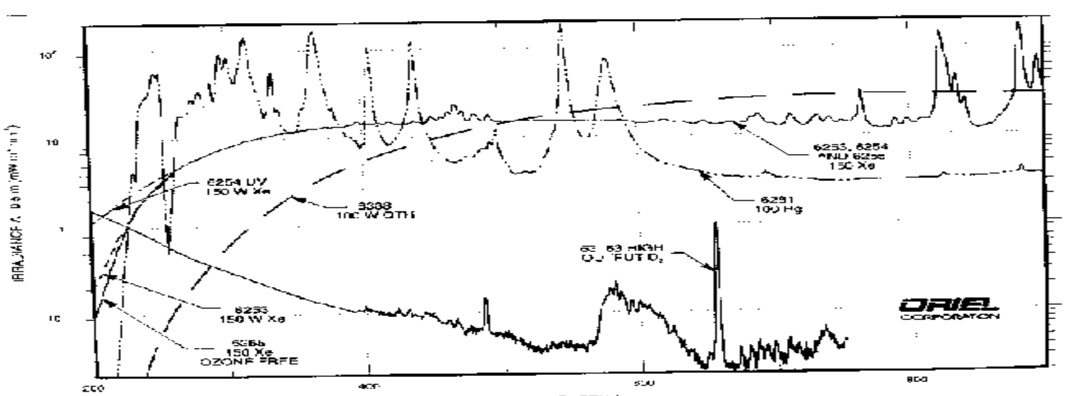
- Figure 3 - Nerst vs. Glowbar, Figure 5 - Discharge vs. Glowbar, Slides

B. Discharge sources , Compare:Black Body, discharge and incandescence

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







(poor version with D2 lamp as well—Figure S_9) also Figure S-4, Figure S-5,

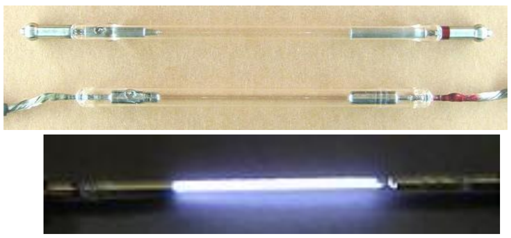
1. Continuum—high pressure.

C-arc–old, stability problem, no window

Xe-arc (also Ar, Xe-Hg, Hg) – 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 uv, 370-180 (envelop) nm–molec. contin.



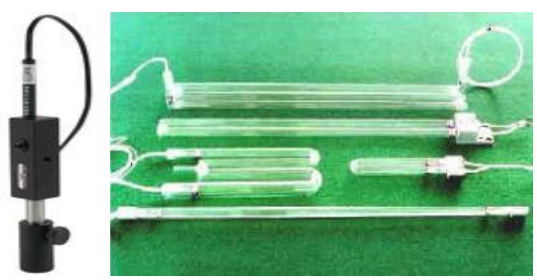
Flash tubes (use in lasers)

Xe arc in ceramic/mirror →

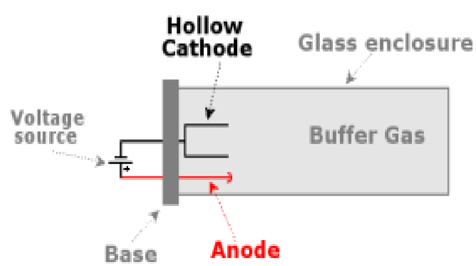
C-arc, ignite between two rods:

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

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



6035 Hg(Ar) Lamp, + various shape tubes



Generic hollow cathode lamp, examples

3.Standards

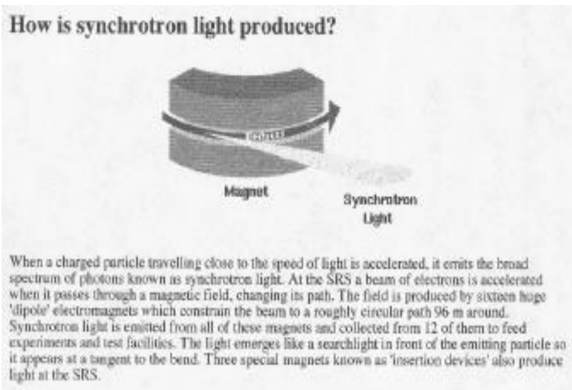
Intensity -- W-I and others (NIST calibrate)
Frequency -- atomic: Hg (simple), hollow cathode: Fe/Th (vis), Ne (red)

Table 1 Usable Wavelengths of Spectral Calibration Lamps (in nm)

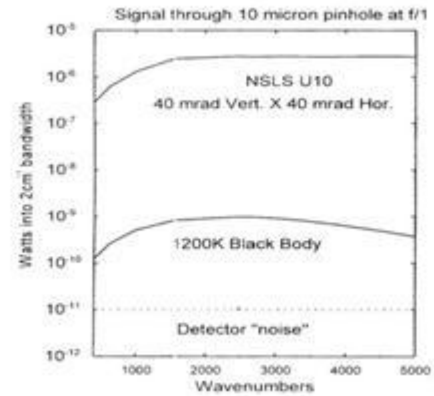
6035 Hg(Ar)	6034 (HgNe)	6033 (Xenon)	6030 (Argon)	6032 (Neon)		6031 (Krypton)
184.9	253.65	418.0	294.3	585.25	More in	427.4
187.1	296.73	419.3	415.9	594.48	Near-IR	432.0
194.2	302.15	433.1	420.1	607.43	for Ne	435.5
253.65	312.57	439.6	427.7	609.62	see	457.7
265.4	313.15[1]	444.8	476.5	614.31	Newport-	461.9
284.8	313.18[1]	446.2	488.0	616.36	Oriel	465.9
302.2	365.02	473.4	696.54	621.73		473.9
312.57[1]	404.66	480.7	738.40	626.65		476.6
313.15[1]	435.84	483.0	750.39	630.48		483.2
313.18[1]	546.07	508.1	751.47	633.44		557.0
320.8	576.96	529.2	763.51	638.3		587.1
326.4	579.07	531.4	772.38[1]	640.11[1]		758.74
345.2	614.31*	554.0	772.42[1]	640.22[1]		760.15
365.02	638.30*	541.9	794.82	650.65		769.45
404.66	640.11[1]*	547.2	801.48	653.29		769.45
435.84	640.22[1]*	597.7	811.53	659.90[1]		785.48
546.07	650.65*	603.6	826.45	660.29[1]		805.95
576.96	703.24*	605.1	840.82	667.83		810.44
579.07	1013.98	609.8	842.46	671.70		811.29
615.0	1128.74	659.5	912.3	692.95		819.00
1014.0	1357.02**	680.5	922.4	703.24		826.32
1357.0	1367.35**	699.1	965.8	717.39		829.81
1692.0	1529.58	823.2	1047.1	724.52		829.81
1707.3	1688.15**	828.0	1331.3	743.89		850.9
1711.0	1692.02**	834.7	1336.7	783.9		877.7
	1694.20**	840.9	1371.8	792.7		975.2
	1707.28**	881.9	1694.0	793.7		975.2
	1710.99**	895.2		794.3		1363.4
	1732.94**	980.0		808.2		1442.7
	1813.04**	992.3		811.9		1523.9
	1970.02**	1262.3		812.9		1533.4
		1365.7		813.6		1678.51
		1473.3		825.9		1689.04
		1541.8		826.6		1689.68
		1672.8		826.7		1693.58
		1732.5		830.0		1816.73
		2026.2		836.6		
		2482.4		837.8		
		2626.9		841.7		
		2651.0		841.8		
				846.3		
				848.8		
				849.9		
				854.5		
				857.1		
				859.1		

C. Synchrotron – different mechanism

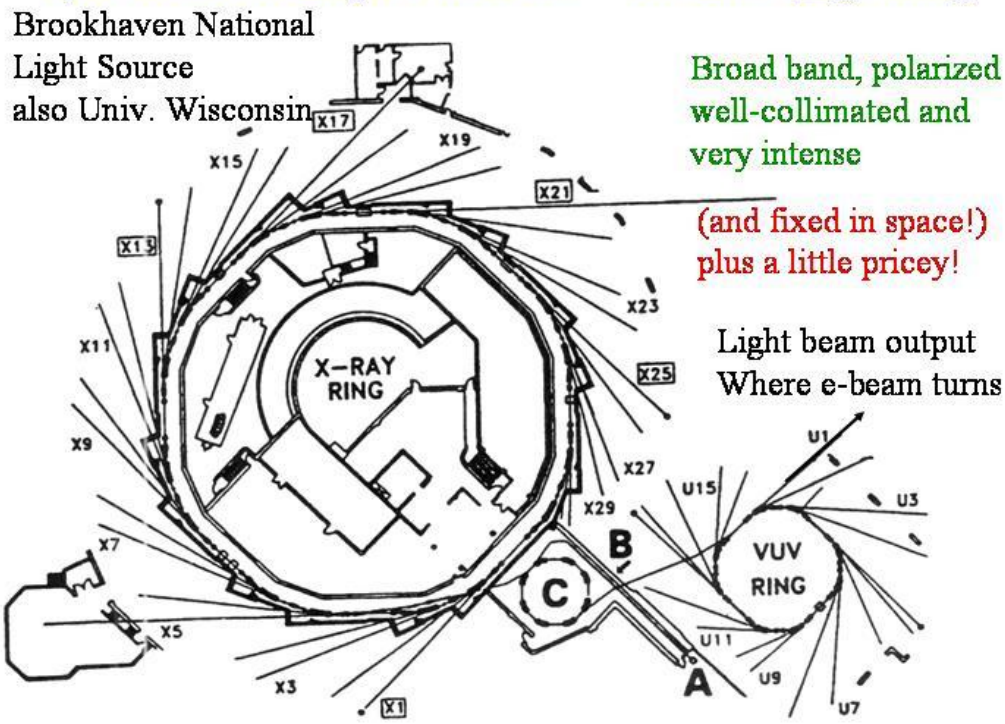
- unique virtues: tunable, collimated, polarized, intense (high freq. pulses)
- – especially useful for uv, vuv , x-ray
- --in IR especially promising for microscopy, high power density
- experiment and operator must go to the source, especially inconvenient



Synchrotron advantage – high *brightness*



Synchrotron Light Sources – the next *big* thing



Homework – part of #1, link here

Homework for Notes 2 (incoherent sources):

Read Chapter 4 Section 1,2, also look at ***sources tutorial on Oriel/Newport*** site

Problems in the book:
For discussion: Ch. 4 - #12,
To hand in eventually: Ch. 4 - # 1

Link to slides shown in lecture

Web sites for lamps:

Oriel Corporation, (purchased by Newport),Lamps section:

(click on either Arc Lamps or Incandescent Sources – note: they spec them at much higher color temps than we discussed)

http://www.newport.com/oriel/

Hamamatsu Lamps:

http://sales.hamamatsu.com/en/products/electron-tube-division/light-sources.php

Ushio America, large selection (IR also Hg arc)--go to Products, then Scientific-Medical

http://www.ushio.com/

Solar Light Co. (commercial sources for home and garden, adaptable sometimes)

http://www.solar.com/sources.htm

Kanthal Glowbars, for heating elements

http://www.kanthal.com/products/trademarks/globar/

http://www.warmvents.com/hot-surface-ignitors.html (surface igniter)

Wikipedia discussion of Nerst Lamsp, - hisortrical interest

http://en.wikipedia.org/wiki/Nernst_lamp

Wikipedia on Halogen lamps

http://en.wikipedia.org/wiki/Halogen_lamp

Other Sites of possible interest (These may be poor links):

Analytical encyclopedia and spectroscopy pages--on-line course in analyticalchemistry

http://elchem.kaist.ac.kr/vt/index.htm

Spectrum page

http://elchem.kaist.ac.kr/vt/chem-ed/light/em-spec.htm

Lamp page

http://elchem.kaist.ac.kr/vt/chem-ed/optics/sources/lamps.htm- blackbody