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Photoluminescence characterisation of the WODEAN samples

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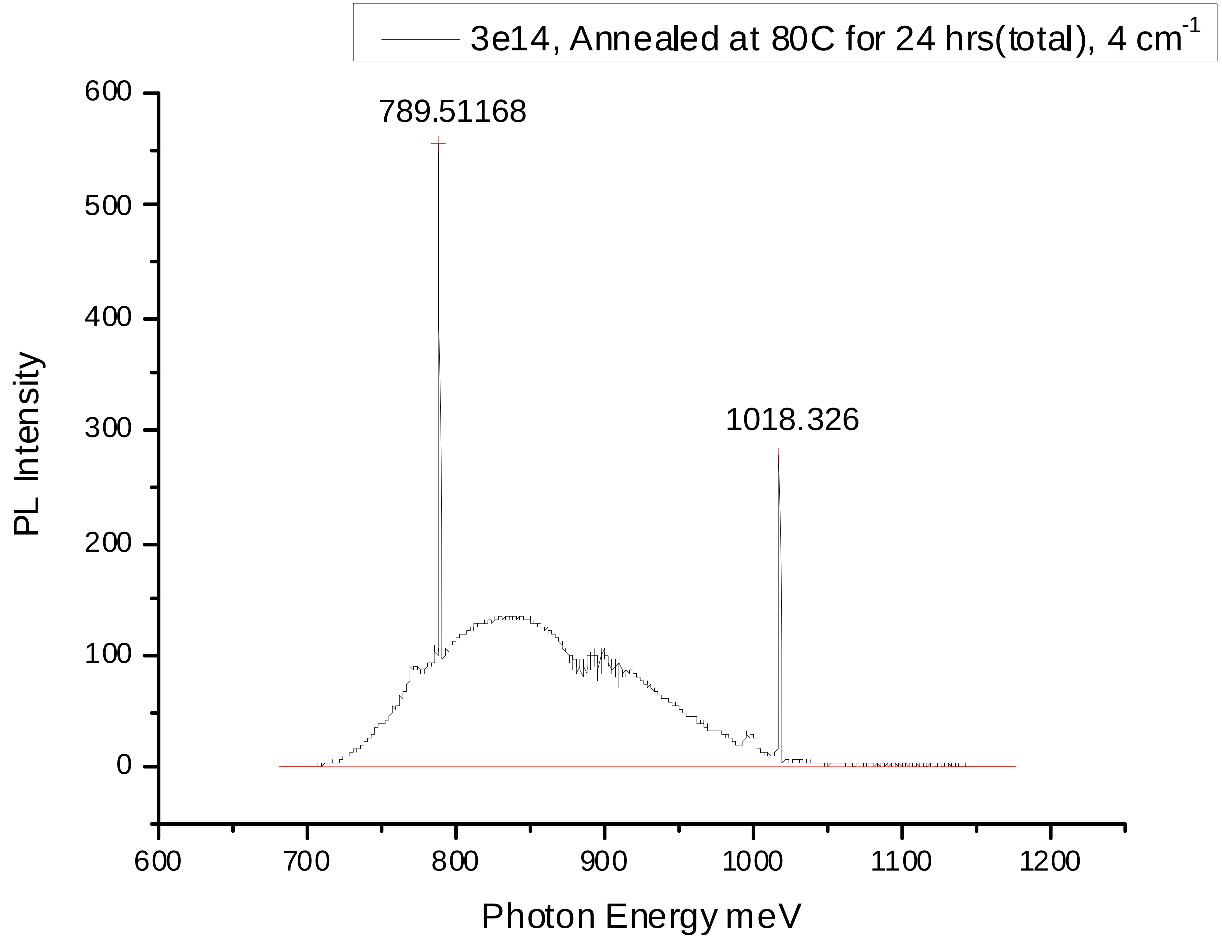
Technical details

- Magnetic Cz samples, irradiated with 1e12 to 3e16 cm^{-2} fast neutrons.
- Photoluminescence spectra measured at ~4 K, in liquid helium.
- Interest is in annealing at 80 C (accelerated room temperature annealing).



Example: 789 meV = C_iO_i, 1018 meV = W (3I ?)

Photoluminescence

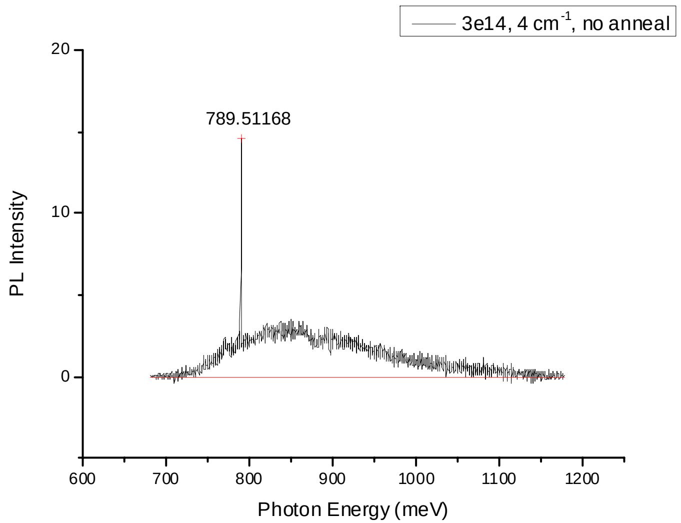
- High energy resolution : unique defect characterisation for sharp lines...
- …but broad band PL is not identified.
- PL must be seen…
- …defects may be non-radiative (VV) or PL quenched by other defects.

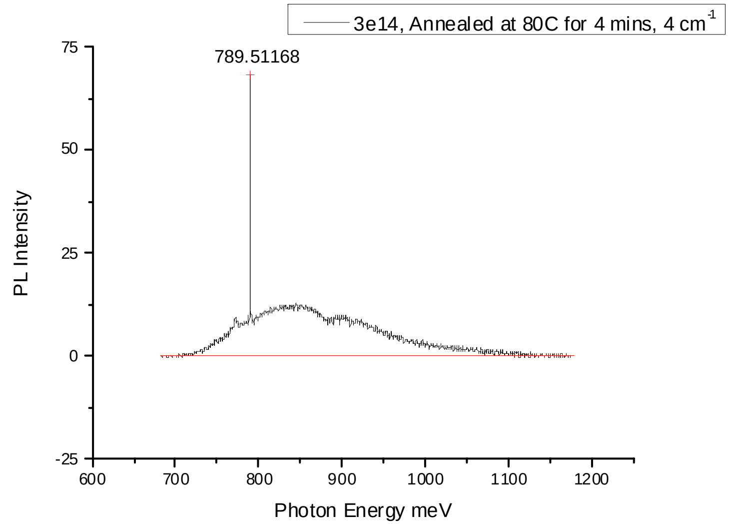
Annealing data

- 7 different fluences (1e12 to 3e16 cm^{-2})
- Spectra as received and 4 anneals at 80 C and one at 450 C
- 42 spectra

- Sample spectra only here

Recovery at 80 C (4 mins)



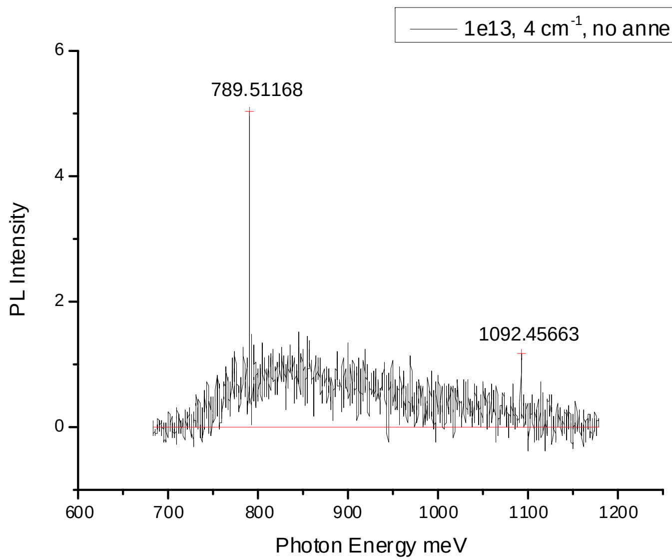


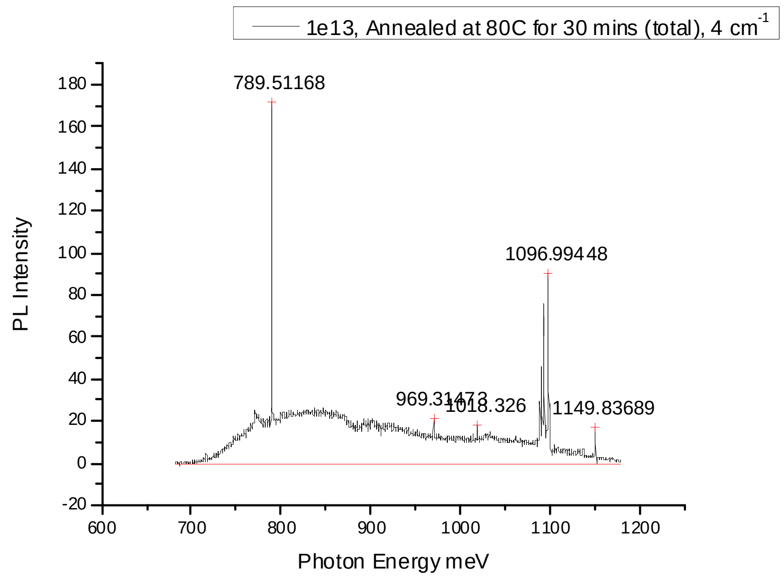
3e14 cm^{-2} no anneal

3e14 cm^{-2} annealed 4 mins

All samples : No change in spectral shape

Recovery at 80 C (30 mins)



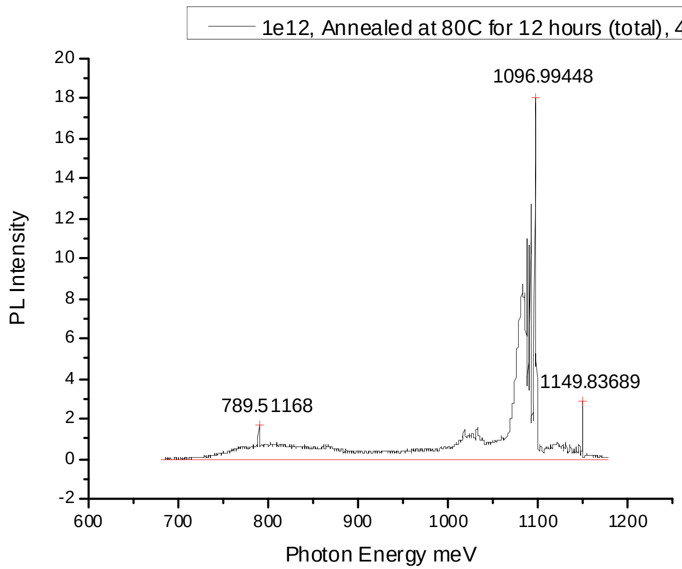


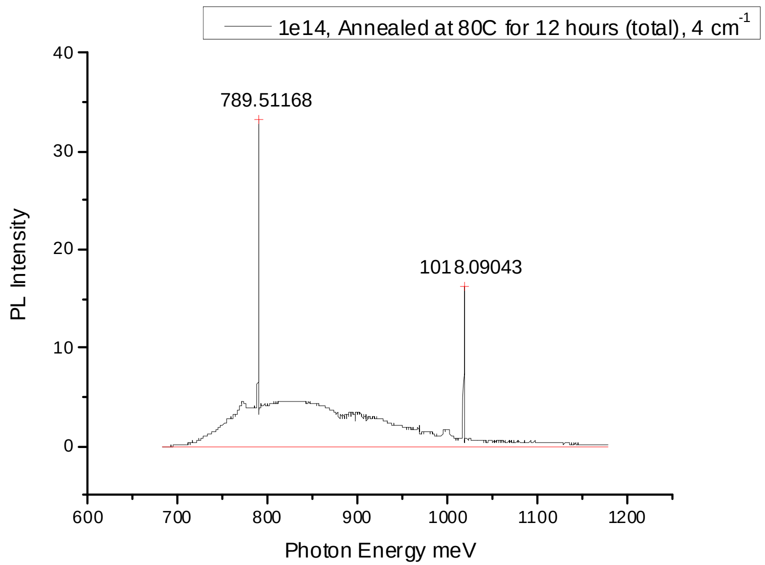
1e14 cm^{-2} no anneal

1e14 cm^{-2} annealed 30 mins

Lower fluences : Recovery of shallow PL, observation of C_iC_s *and W (3 I's)*

Recovery at 80 C (12 hrs)





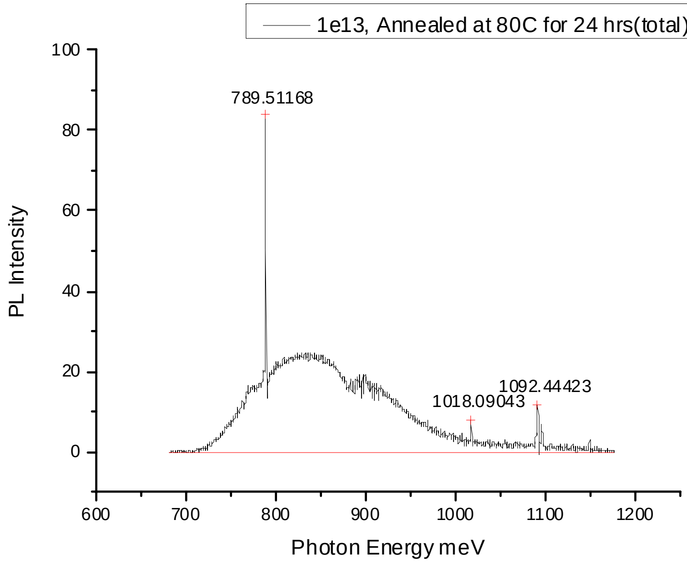
1e12 cm^{-2} annealed 12 hrs

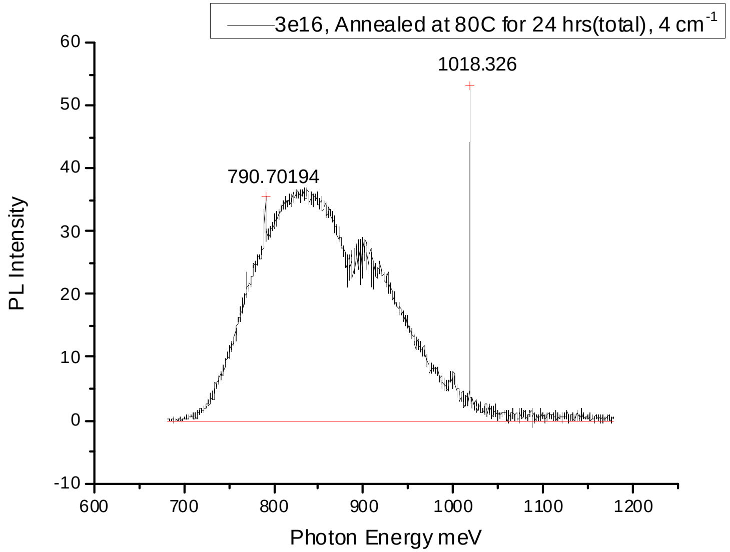
Lowest dose: almost complete recovery.

1e14 cm^{-2} annealed 12 hrs

Higher fluences: C_iO_i and W but 1e16, 3e16 no change

Recovery at 80 C (24 hrs)





1e13 cm^{-2} annealed 24 hrs

3e16 cm^{-2} annealed 24 hrs

C_iC_s and W , with ratio of PL from W to C_iO_i increasing with fluence especially at the highest doses.

Summary of annealing

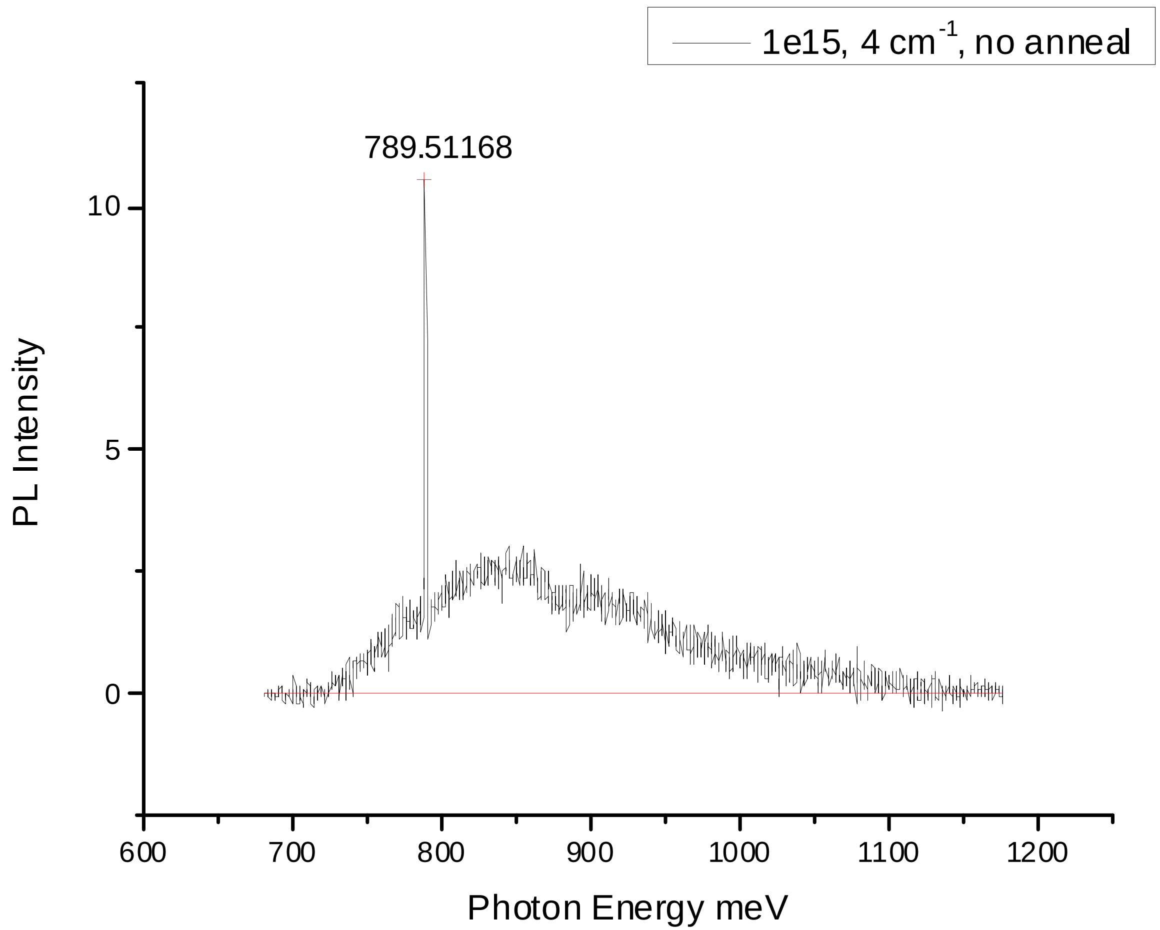
- As received: low PL intensity, C_iO_i plus broad band
- At 80 C, no change in bandshapes after 4 mins.
- After 30 mins, start of observing weak C_iC_s and W; W continues to increase after 12 hrs and 24 hrs.

Radiation damage and C

- C_s + I --> C_i
- Thermal diffusion of C_i is
- D = 0.44 exp (-870 meV/kT) $cm^2\ s^{-1}$, so
- C_i + O_i --> C_iO_i

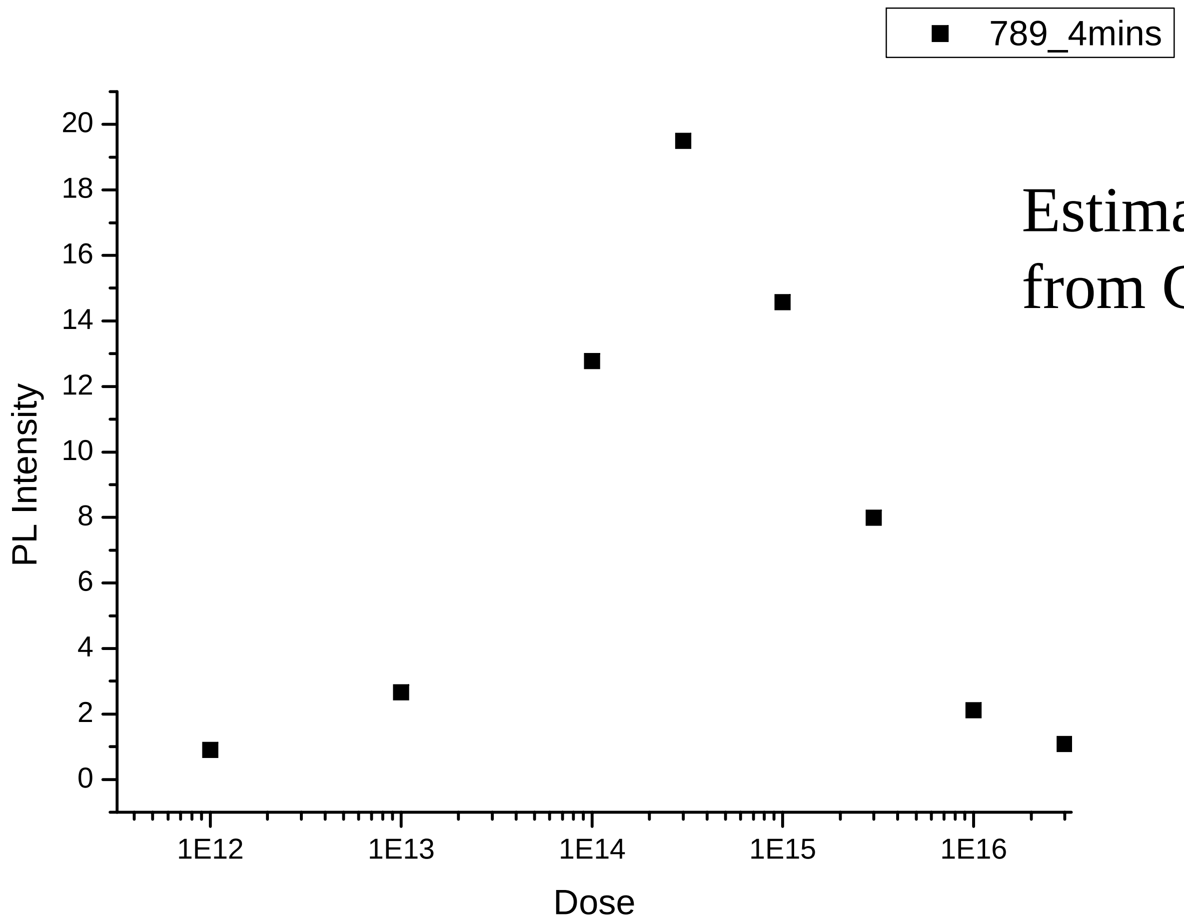
Carbon interstitials C_i : PL at 856 meV: Not seen

C_iO_i : PL at 789 meV : observed :



Carbon content

- [C] < 2.5e15 cm^{-3} from SIMS.
- At larger radiation fluences, > 3e15 cm^{-2} , the concentration of generated I's exceeds [C]
- $C_s + I \dashrightarrow C_i \quad C_i + O_i \dashrightarrow C_iO_i$
- $C_iO_i + I \dashrightarrow IC_iO_i$ (Destruction of C_iO_i)



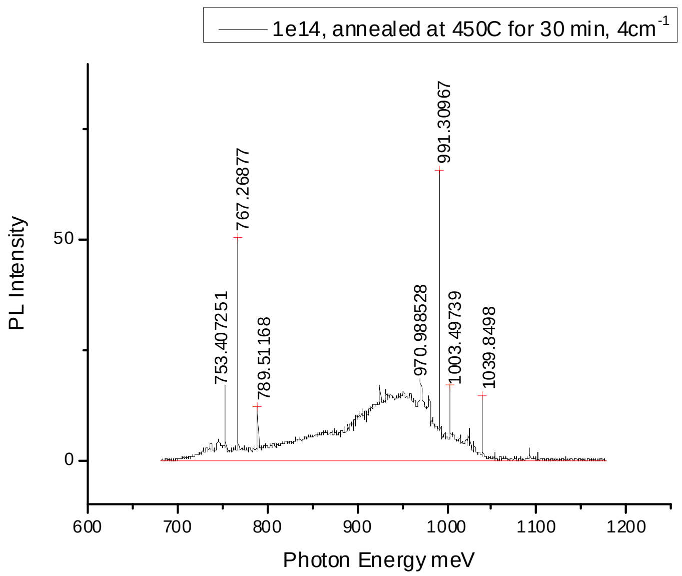
Estimate [C] from C_iO_i

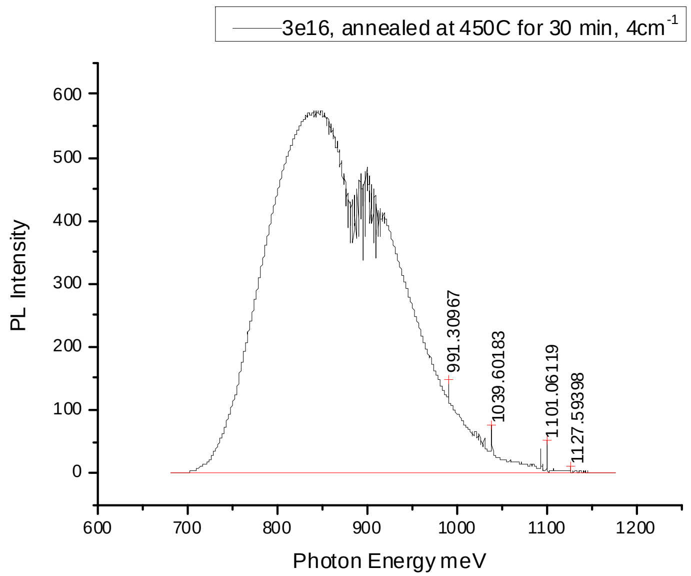
For 2 MeV electrons, peak 789 meV is when creation of I's is 0.75 [C]. For a production rate of R = 0.7 cm^{-1} , peak at (5 to 6) e14 cm^{-2} implies [C] ~5e14 cm^{-3} .

Summary / Next steps

- PL allows monitoring of annealing at 80 C.
- In principle estimate of carbon concentration : [C] ~5e14 cm^{-3} ?
- Next:
- Careful annealing in 20 to 80 C range, to give kinetics of W (3 I's?) defect.

Anneal at 450 C (30 mins)





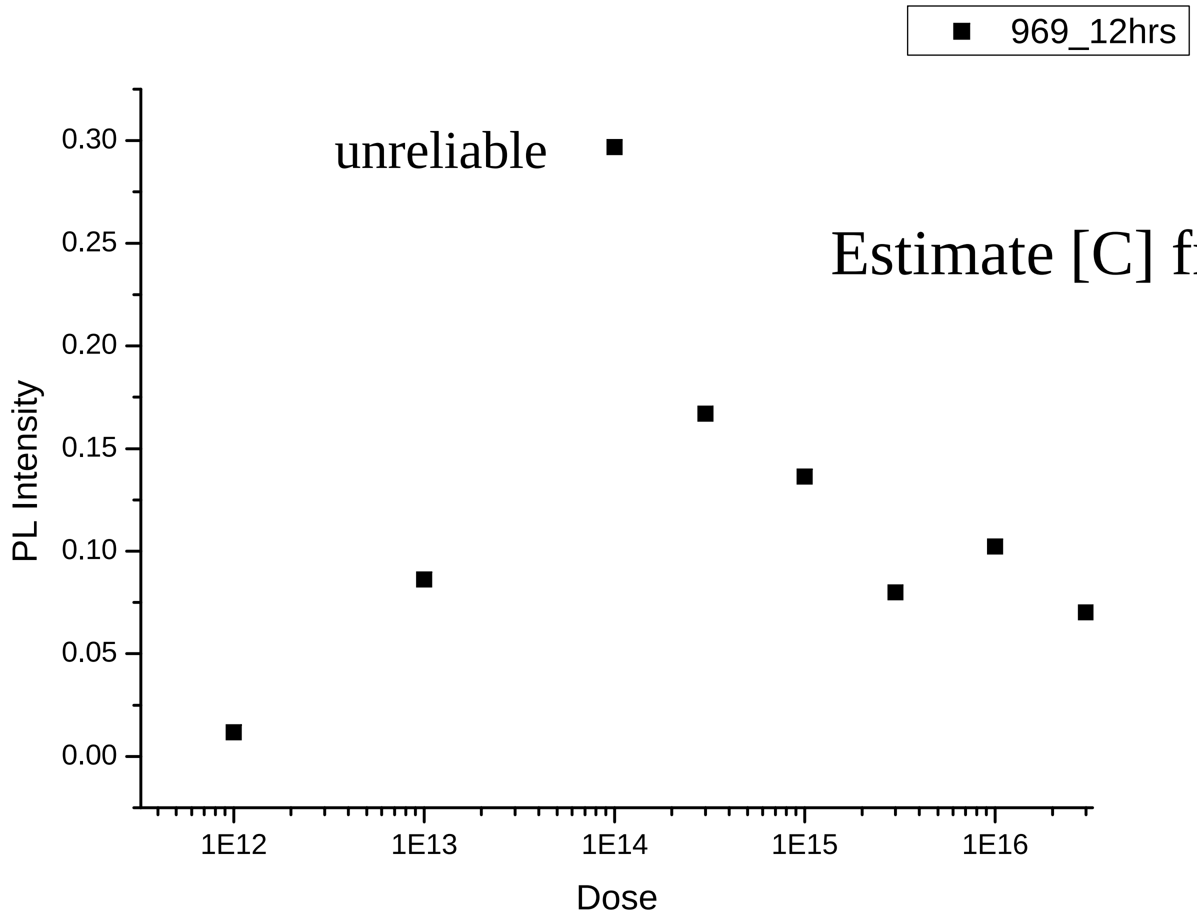
1e14 cm^{-2} and below: broad band gone

3e14 cm^{-2} and above: broad band persists at increasing expense of sharp lines.

Shown is 3e16 cm^{-2}

Problems: 1. Quenching

- From ion-implantation *at nominal RT*, PL is quenched when the mean distance between VVs is less than ~50 atoms.
- Assume production rate for VV of 1.3 cm^{-1}.
- At maximum fluence, 3e16 cm^{-3}, the mean VV separation is 110 atoms.
- Implies quenching is not important.



Estimate [C] from C_iC_s

For 2 MeV electrons, peak 969 meV with [C]<<[O] is when creation of I's is ~0.25 [C]. For a production rate of R = 0.7 cm^{-1} , peak at 2e14 cm^{-2} implies [C] = 6e14 cm^{-3} .