WP-6 – Thin-Ladder R&D

- ***Objective – to design a CCD support structure with the following properties:***
  - **Complete assembly must have ultra-low mass *(<<0.4%* X_0 *– SLD VXD3)***
  - **CCD adopting a non-planar 3-d profile is tolerable at ~few tens of micron level, but must be repeatable to ~micron level with temperature cycling *(~ ± 50°C)***
  - **CCD must be mechanically stable at ~micron level wrt small temperature excursions *(~ ± 5°C)* – no "metastable" behaviour**
  - **CCD capable of planarisation at each end for bump-bonding of Readout Chip**
  - **Overall assembly sufficiently robust for safe handling *(with appropriate jigs)***
  - **Structure must allow use of evaporative gas-cooling *(low-impedance to gas-flow)***

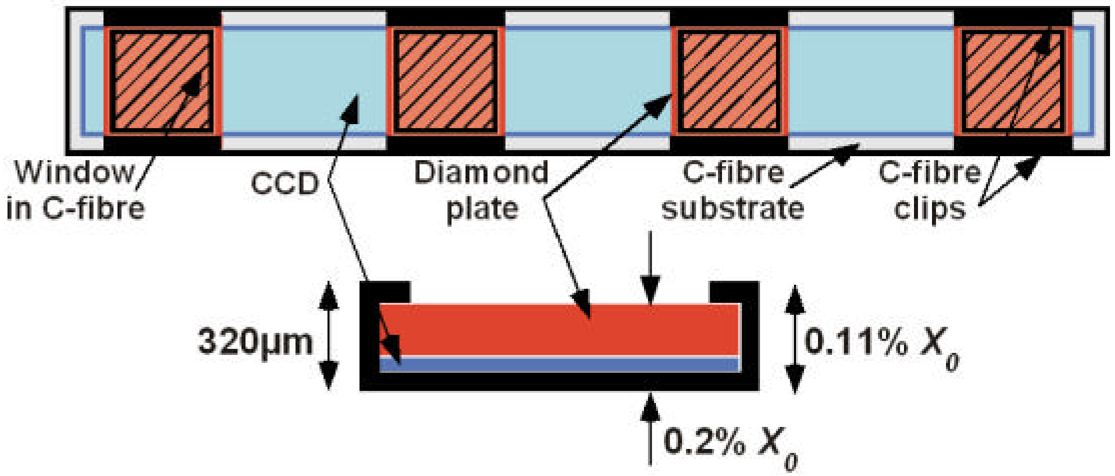
Options currently under study

- Three main approaches:
- In order of diminishing X/X_0 –
  - Fully-supported CCDs – thinned Si bonded to 3-d rigid substrate *(e.g. Be)*
  - Semi-supported CCDs – thinned Si attached to planar substrate, with rigidity achieved by tensioning substrate in z
  - Unsupported CCDs – thinned Si with no substrate, rigidity of effective membrane achieved by tensioning Si in z
- Only the last two have been studied so far
- Unsupported Si option very attractive from low-mass aspect, *but …*
  - CCD processing → severe differential thermal contraction effects → curling
  - Longitudinal curling removed by tensioning in z, but lateral curling → instability

Semi-supported CCD mounting structures

- **Unsupported Si option very attractive from low-mass aspect, *but …***
  - **CCD processing → severe differential thermal contraction effects → curling**
  - **Longitudinal curling removed by tensioning in z, but lateral curling → instability**
  - **Problem of joining B2–B5 ladders at z = 0 *(reliability of narrow adhesive bond)***
  - **Handling *(bump-bonding, testing, assembly, …)* of ladders could be a potential *(probable?)* nightmare → low yield**
- **Lateral curling could be reduced by cross-bracing *(Si, ceramic, … ?)***
  - **Increase in X/X_0 in several local regions**
- **Semi-supported Si option currently being studied**
  - **Several possible techniques and different materials – all have *pros* and *cons*!**
  - **Simulation very important to narrow down options – much faster than making physical models**

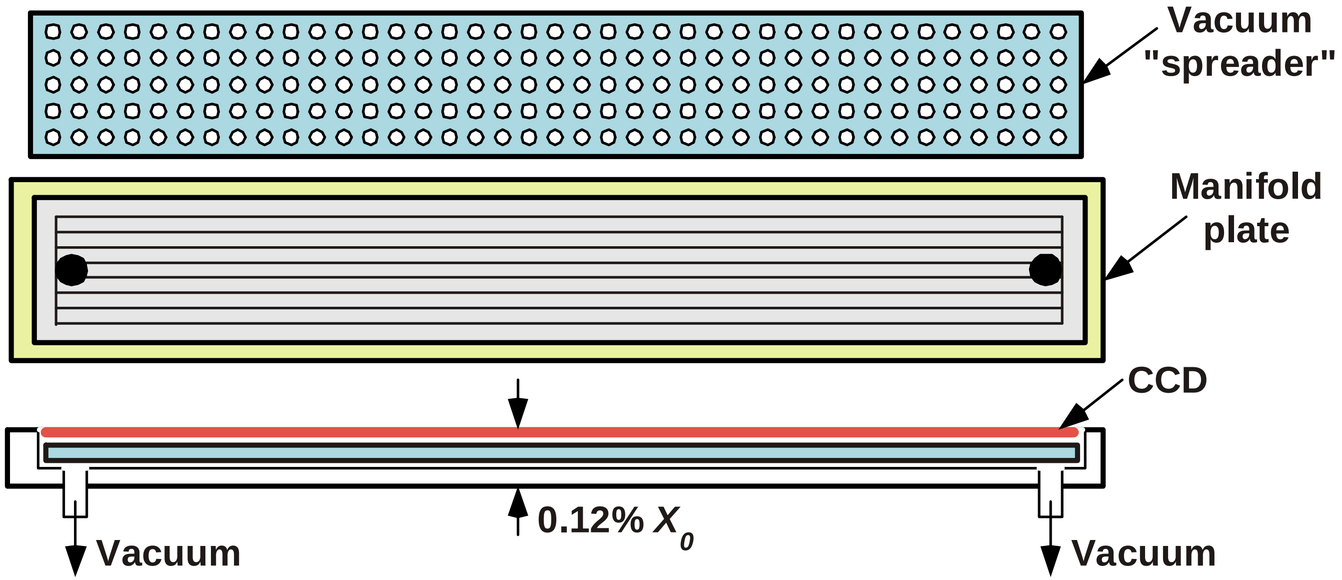
C-fibre substrate with CVD diamond retainers



- CCD free to slide between substrate and diamond plates
- Plates + substrate planarise CCD
- 200µm CVD diamond – 0.16% X_0
- 50µm C-fibre – 0.02% X_0
- Min layer thickness – 0.04% X_0

- ***Potential problems:***
  - **Layer thickness increases by factor ~5 *(0.04% X_0 – 0.2% X_0)* for ~50% of active area**
  - **Tolerances on plate-substrate gap – thermal contraction effects**
  - **Longitudinal borders → extra material in ladder overlap regions**
  - **Mechanical damage to CCD gate/bus structures**
  - **Possible effect on gate capacitance?**
  - **Lateral curling of CCD in free regions – adhesive still needed?**

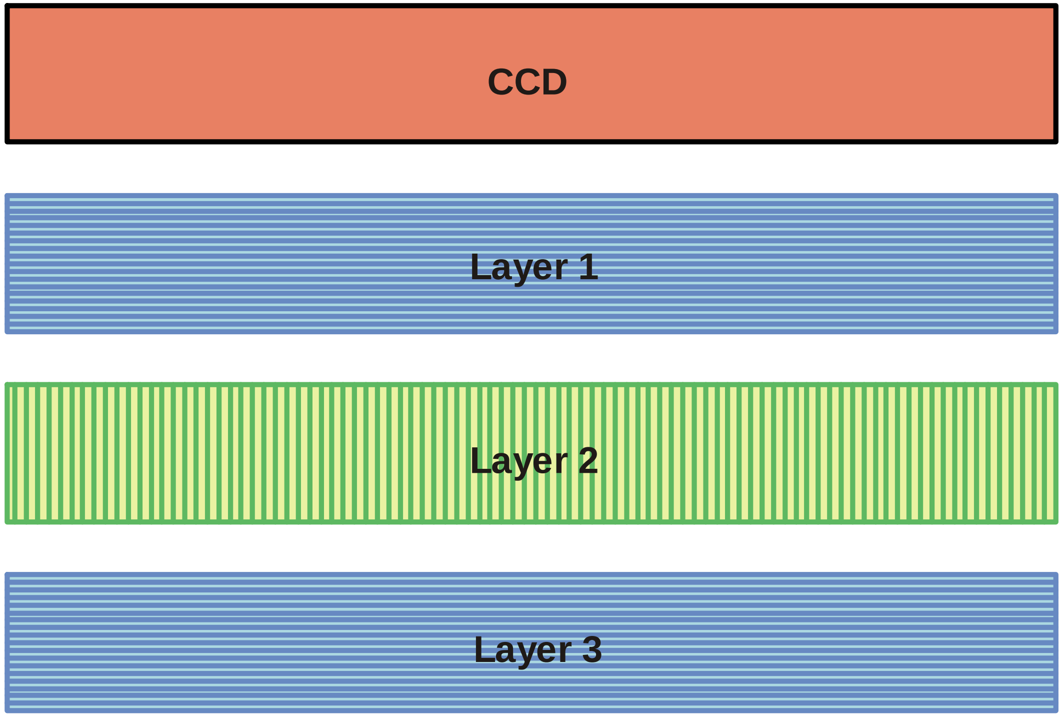
C-fibre/Be substrate + vacuum



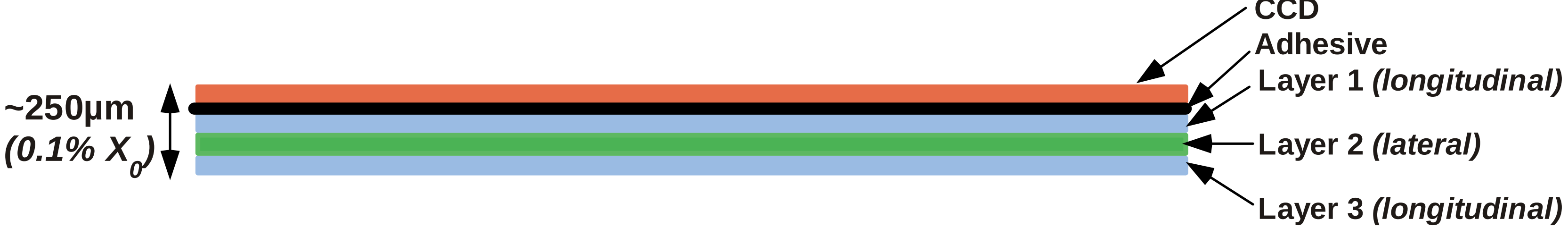
- **C-fibre *(Be)* – 100µm thick manifold, 200µm thick vacuum “spreader”**
- **CCD pulled flat by applied vacuum, *via* “spreader”**
- **Uniform low layer thickness –**
  0.12% X_0 *(C-fibre)*
  0.09% X_0 *(Be)*

- ***Potential problems:***
  - **“Spreader” *(=substrate!)* could distort from planar with stress-induced matrix of holes**
  - **Overlap of in-barrel ladders complicated due to longitudinal borders of manifold plate and orthogonal vacuum pipes and introduce more material in overlap regions**
  - **Repeatability of CCD position with vacuum cycling**
  - **Handling – bump-bonding Readout Chip, vacuum retention and transfer, assembly, …**
  - **Loss of vacuum MUST produce a fail-safe state – retaining clamps may be needed**

C-fibre bonded substrate

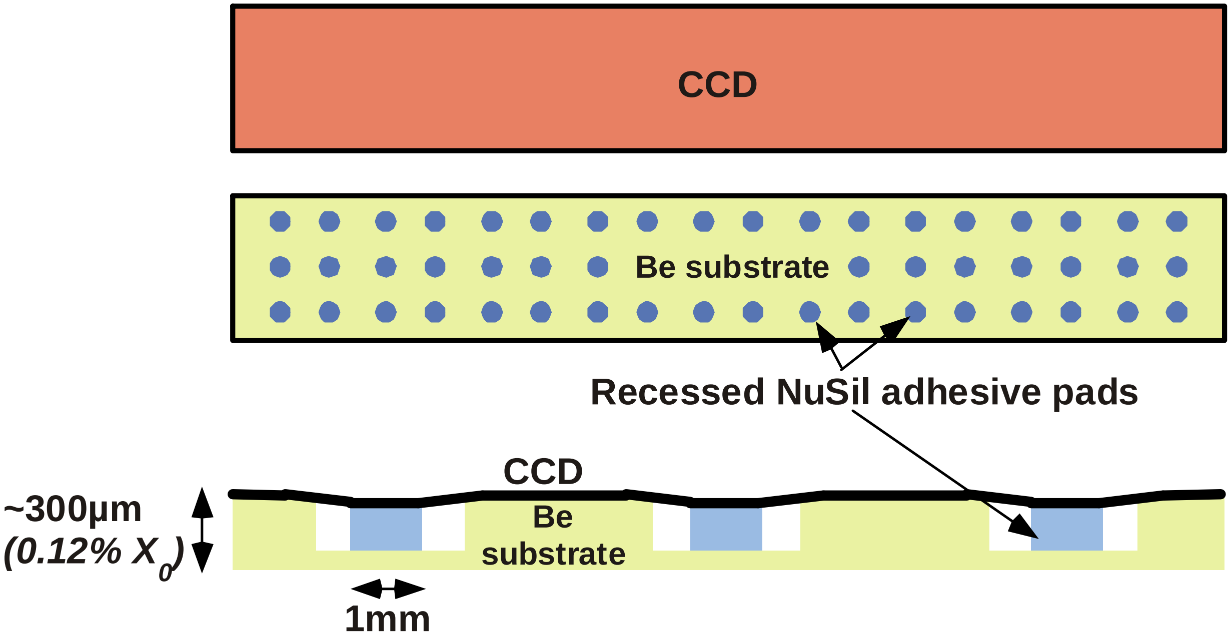


- C-fibre diameter → 10µm
- Sheet thickness → 60µm
- 3 orthogonal layers → ~200µm
- C-fibre CTE < Si CTE, so Si in tension along ladder @ -50 °C
- CTE tuneable to 0 in principle
- Further external tensioning can be used to remove any unbalanced longitudinal bow



- ***Potential problems:***
  - Early test samples showed very poor surface quality *(large diameter C-fibres?)*
  - Much more study needed – many new variants now appearing – but difficult to simulate

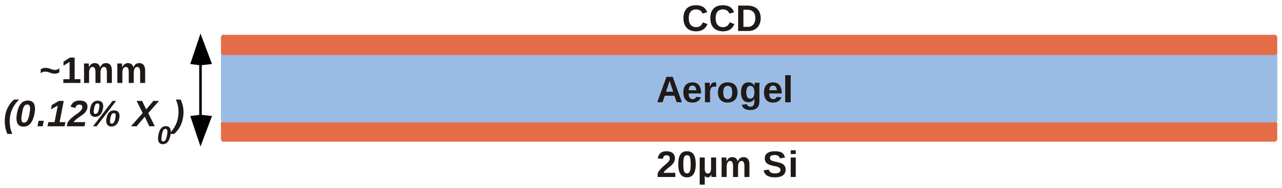
Floating Si on Be substrate



- CCD bonded with compliant adhesive pads *(e.g. NuSil)* to thin *(250µm)* Be substrate
- On cooling, differential thermal contraction → Si into tension → NuSil columns tilt
- Layer thickness → 0.12% X_0
- 1mm diameter NuSil columns inside 2mm diameter wells 200µm deep in Be substrate
- On cooling, NuSil contracts more than Be → pulls Si down on to Be surface

- ***Potential problems:***
  - CCD surface may become dimpled – magnitude of effect and repeatability unknown
  - May need very fine pitch of NuSil pad matrix → difficult assembly procedure, weakened substrate, complex non-uniform layer thickness *(X/X_0), …*
  - Simulation crucial – early results from ANSYS look promising

Aerogel substrate



- 3-layer sandwich made from ~1mm Aerogel between thinned *(20µm?)* CCD and 20µm Si balancing membrane
- Silica Aerogel chemically bonds to Si *(CCD and compensating membrane)*
- Si has higher CTE so on cooling it is put into tension – Aerogel in compression
- *Potential problems:*
  - If attachment needs to be done at time of Si processing – adds complexity
  - What happens at ends of ladder – bump-bonding of Readout Chip?
  - B2 – B5 ladders have pairs of CCDs – is Aerogel strength alone sufficient in the inter-CCD gap region *(tensioning impossible – Aerogel weak in tension)?*
  - Needs much more study – early ideas only

◆ *Conclusions*

- **Several interesting and ingenious mechanical ideas**
- **Some novel materials now being investigated**
- **Making physical test structures takes time, so simulation is vital for guidance → avoid time-consuming dead-ends**
- **Many potential show-stoppers – differential CTE effects, X_0, bump-bonding of Readout Chip, handling**