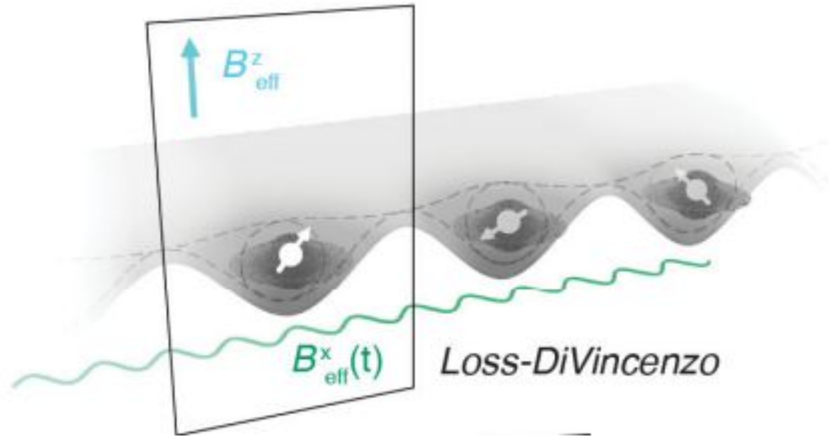
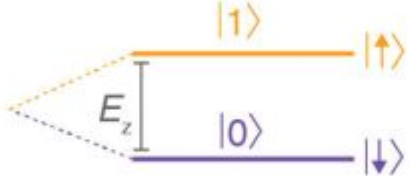
Strain in Si/SiGe Quantum Well

By Carl Liu

Spin Qubits

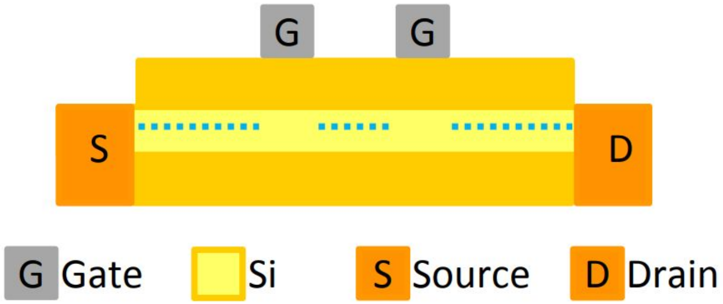


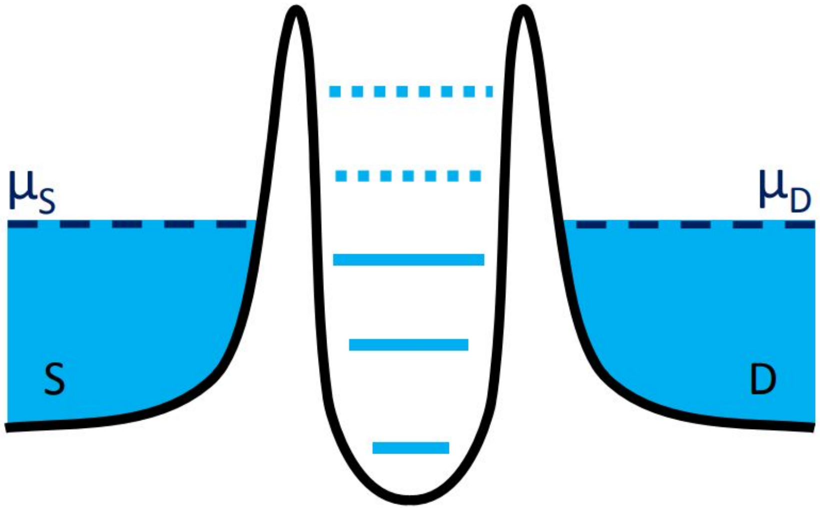


- Uses particle spin to create a 2 level system.
- Loss-Divincenzo uses electron spin
- Static Magnetic Field causes Zeeman splitting.
- Gates can be applied by time varying magnetic fields.

Si/SiGe Quantum Wells

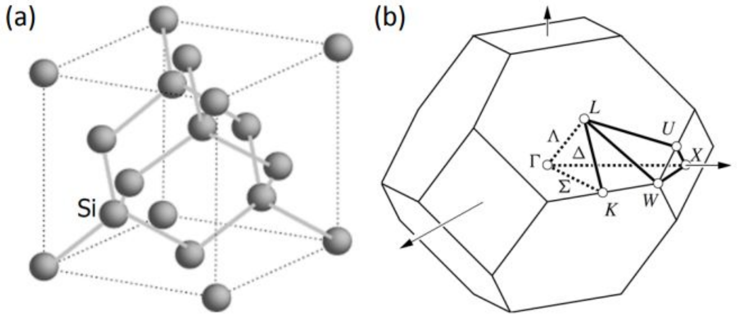
Si/SiGe quantum wells are made of a layer of Silicon sandwiched between two $Si_{1-x}Ge_x$ layers. Usually x≅0.30



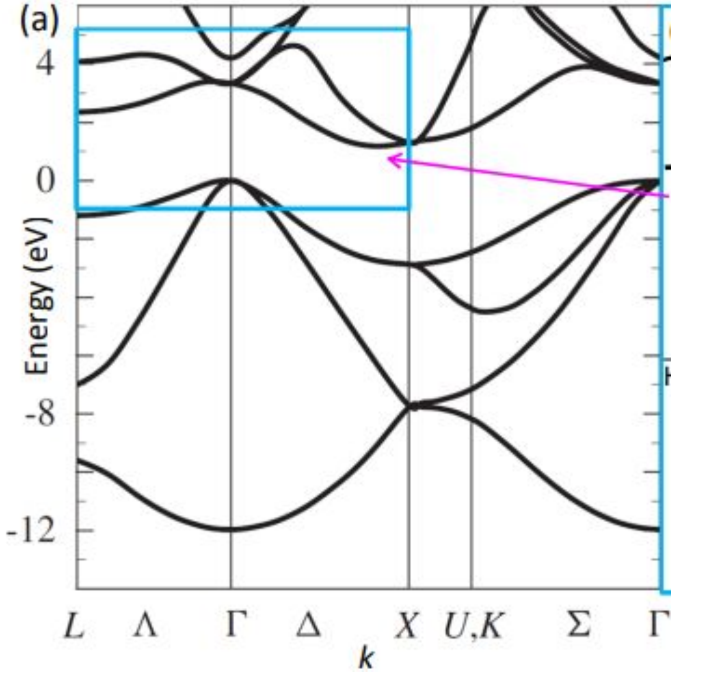


- 2D electron gas in Silicon layer.
- Top Gates provide potential to trap electrons.
- Source, Drain supply electrons for the well.

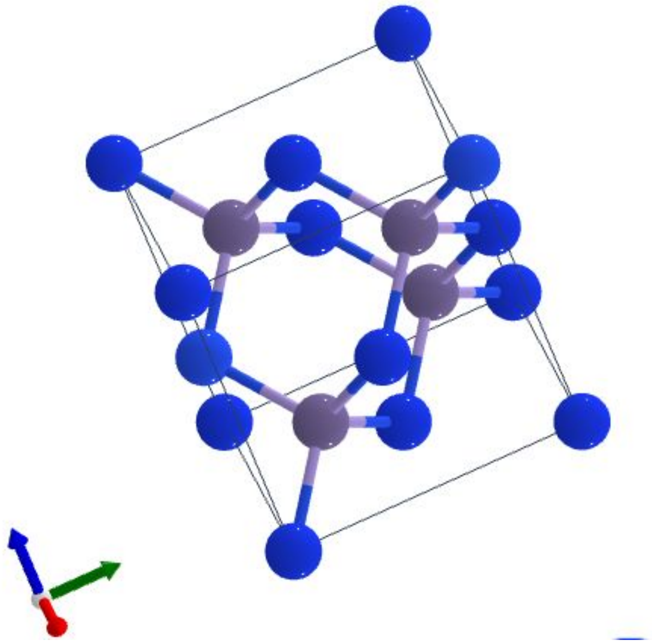
Silicon Properties



- Silicon has cubic symmetry
- Lattice constant of 5.44 Angstroms
- Conduction band minimum has 6 fold degeneracy
- Silicon isotopes with 0 nuclear spin are abundant
- ^{28}Si has a natural abundance of 92.23%

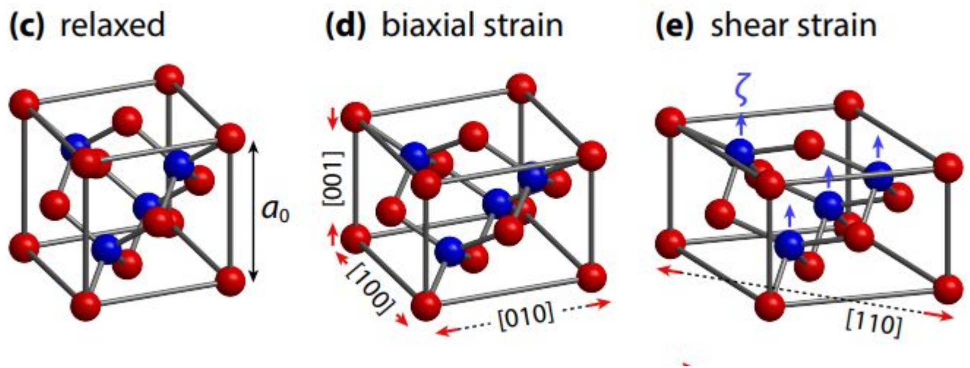


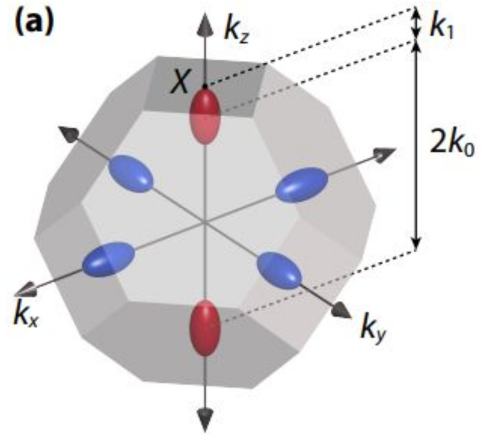
SiGe Properties



- Same cubic structure as silicon
- Germanium is in the same column as silicon
- Larger mass than silicon
- SiGe Lattice Constant of 5.54 Angstroms

Strain In Silicon

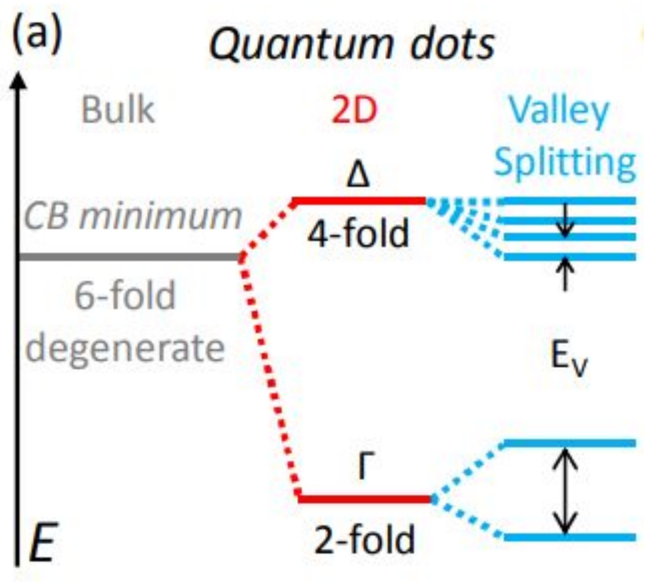




- Silicon is strained biaxially by the mismatch between SiGe and Si lattice constant.
- Stretched in the 100 and 010 direction
- Compressed in the 001 direction

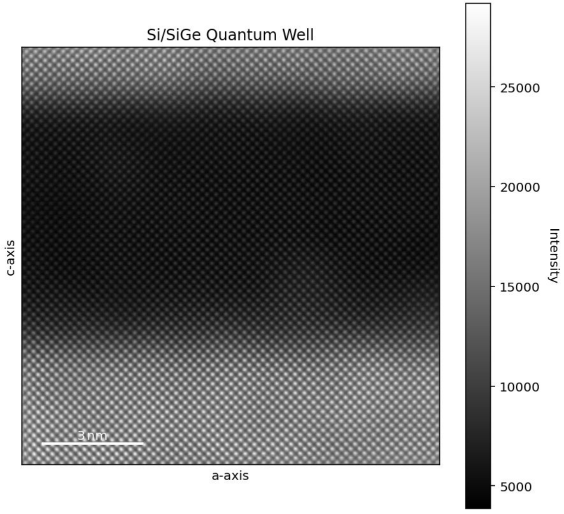
- Shear strain can also be present.
- Strain causes lifting of degeneracy. In Silicon conduction band

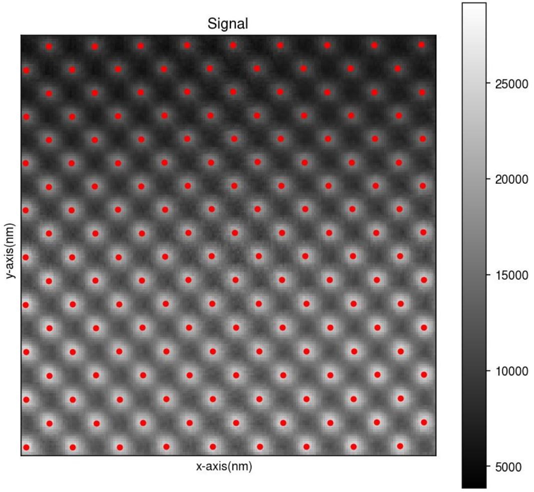
Valley Splitting Due to Strain



- Biaxial Strain lifts the 6-fold degeneracy of conduction band minimum.
- Δ and Γ could be 10s of meV apart
- Shear strain, interface sharpness, and germanium concentration are all factors that lead to further valley splitting
- Further Γ splitting on the order of around 0.1meV - 1meV

Analysis of Si/SiGe Sample

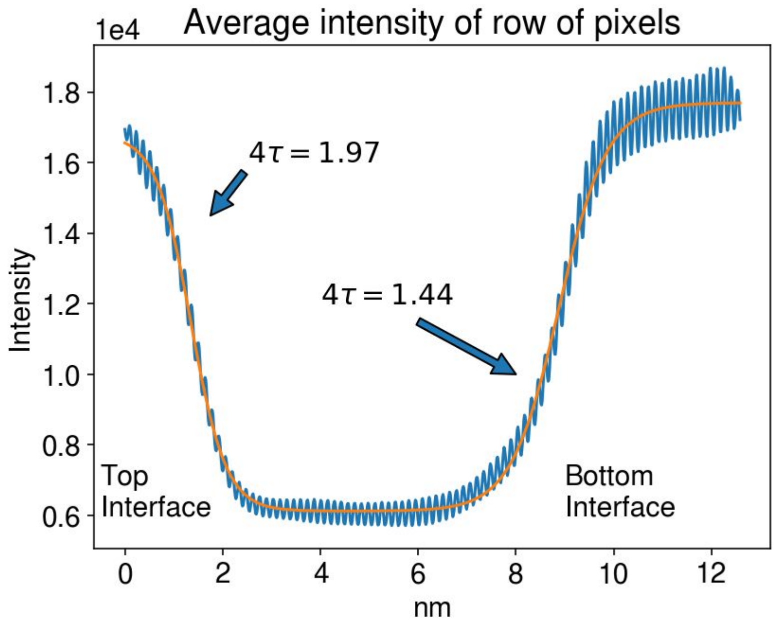




- HAADF-STEM provides Z-contrast
- Intensity corresponds to Germanium concentration

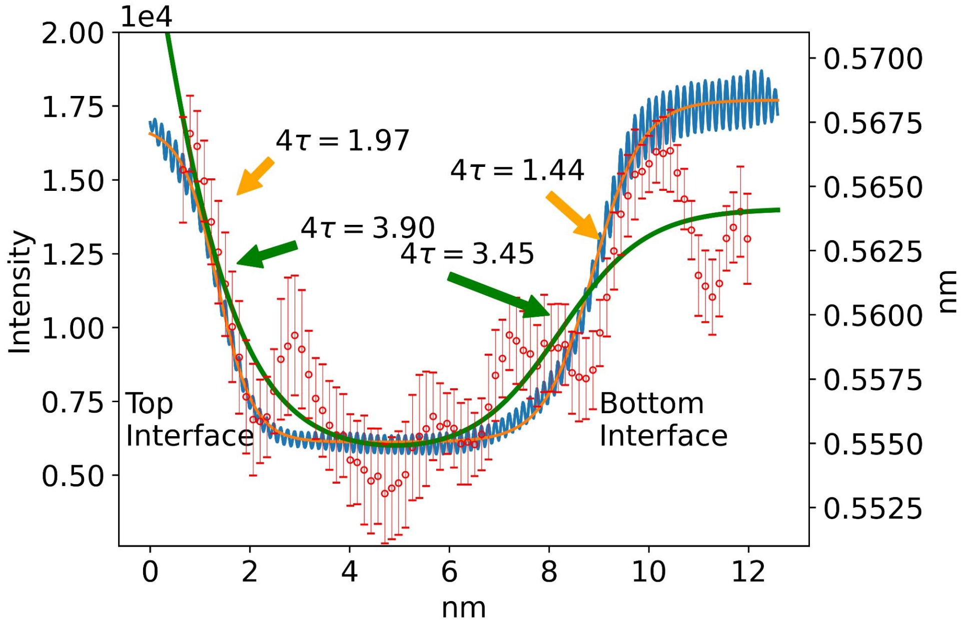
Position of individual atoms can be determined using gaussian peak fitting

Analysis of Si/SiGe Sample



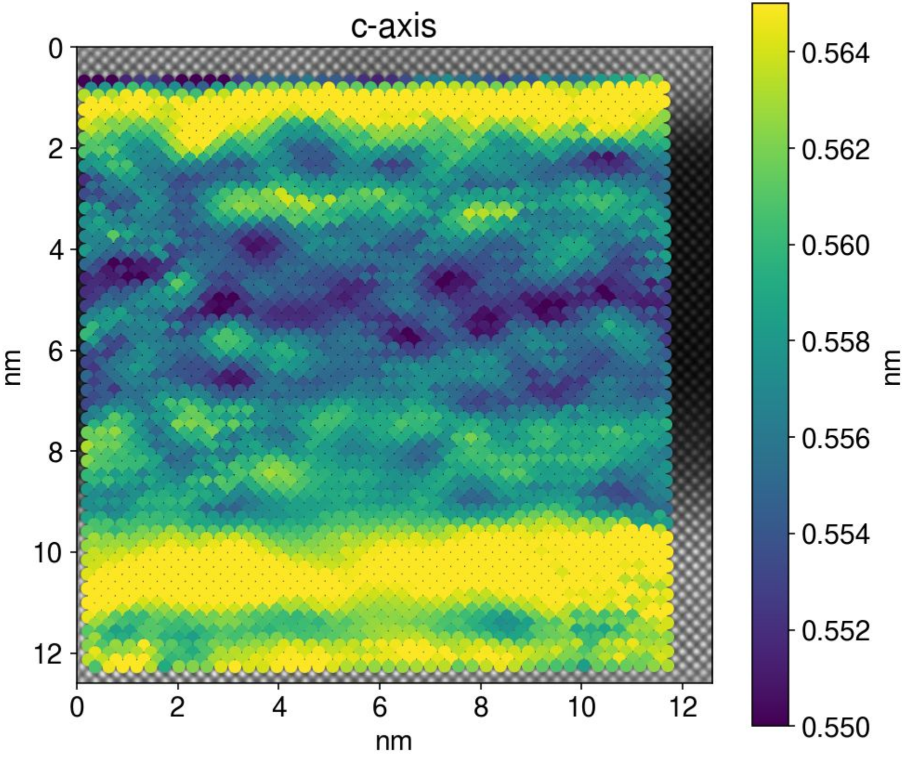
- Intensity can be used to determine Germanium concentration and thus quantum well region

Analysis of Si/SiGe Sample



- Local lattice constant in y direction follows similar curve to intensity
- Smaller lattice constant in well corresponds to high silicon concentration
- Non-uniform lattice

Analysis of Si/SiGe Sample



- Non uniform strain
- Can affect confinement potential of the well
- Cause unwanted quantum dots

References

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