Tailoring the nature and strength of electron-phonon interactions in the $SrTiO_3$ (001) 2DEG

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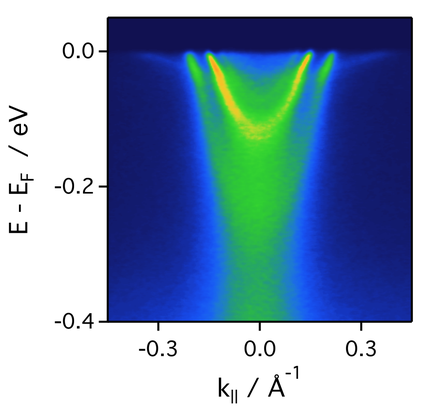
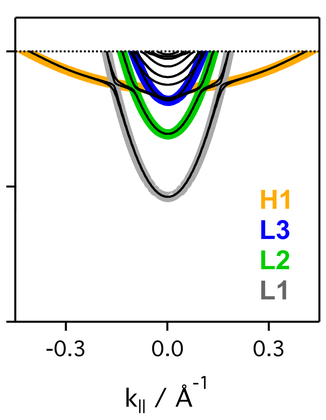
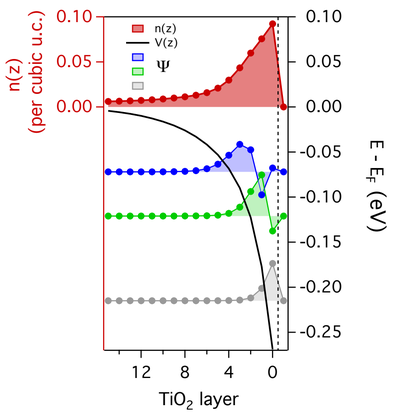
Abstract

The two-dimensional electron gas (2DEG) at the interface of the band insulators $LaAlO_3$ and $SrTiO_3$ has become a central figure in the emerging field of oxide electronics. Understanding it's unusual properties, such as gate-tuned superconductivity and magnetism, has been hampered by the lack of experimental information on the underlying many-body interactions. In the context of superconductivity, electron-phonon interaction is of primary interest. Here we present a high resolution ARPES study of the carrier density dependence of the electronic structure and electron-phonon interactions in the analogous 2DEG at the $SrTiO_3$ (001) surface.

$SrTiO_3$ surface 2DEG electronic structure

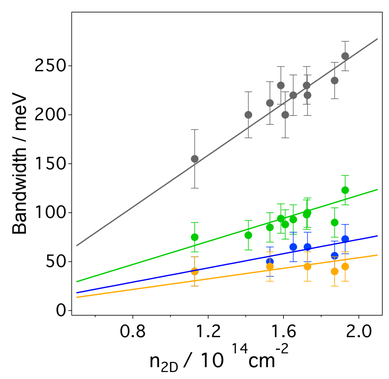


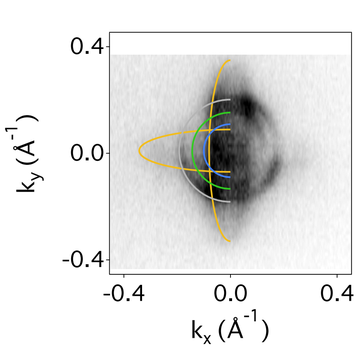




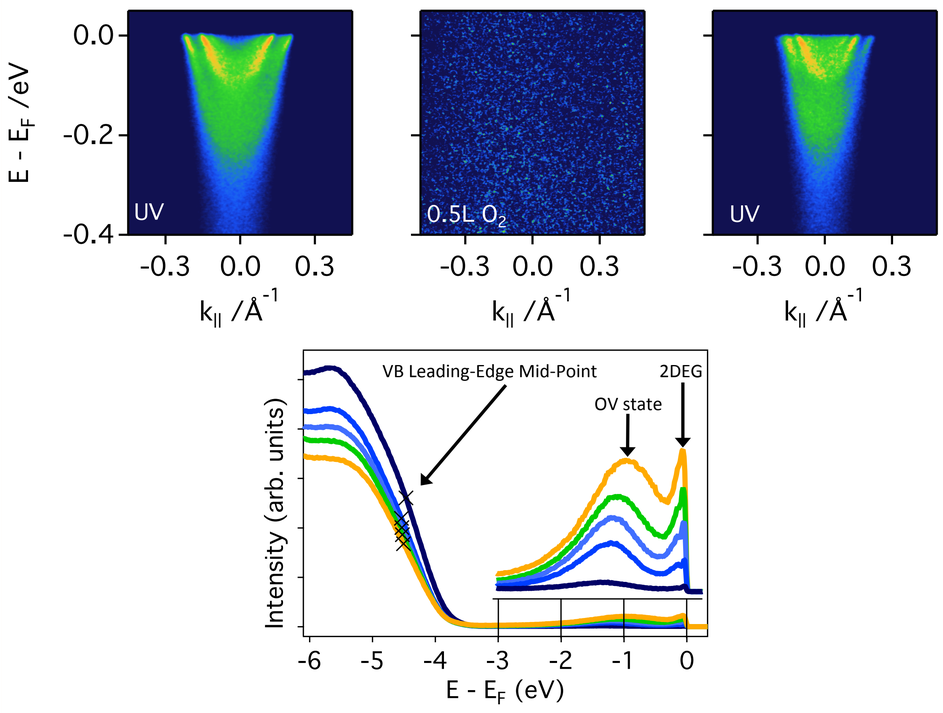
P.D.C. King *et al.*, Nature Communications, 5, 3414 (2014)

- Self consistent tight binding supercell calculations reproduce the experimentally observed ladder of subbands
- The wavefunction is highly confined for the first subband and progressively extends into the bulk for the higher subbands
- The density dependence of subband bandwidth strongly supports a picture of quantum confinement

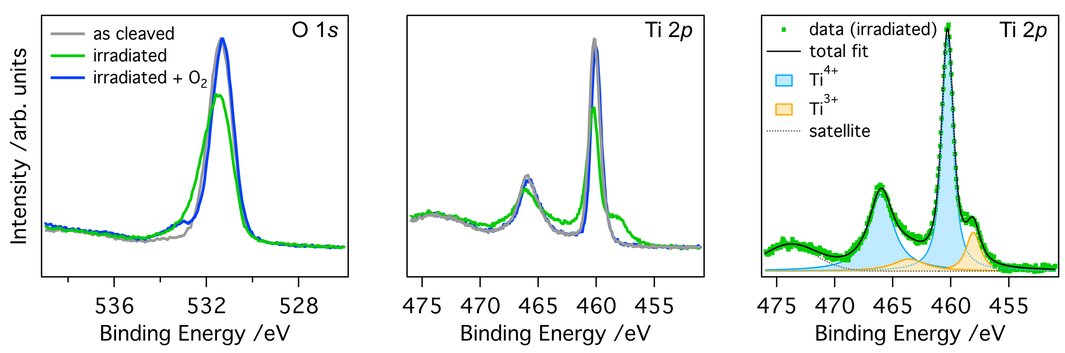


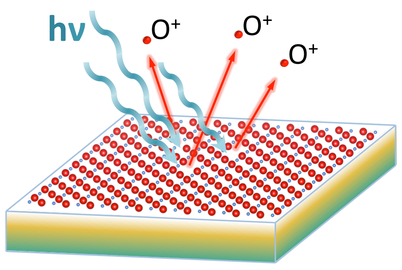


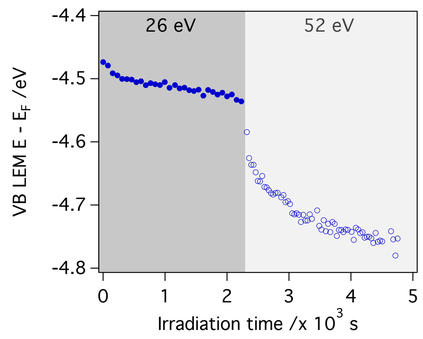
Origin of the $SrTiO_3$ Surface 2DEG



- UV irradiation of the surface induces positively charged oxygen vacancies which are screened by an accumulation layer of electrons
- Itinerant electrons become quantum confined and orbitally-polarized
- Core level spectroscopy reveals ≈1 localized and ≈1 itinerant electron per oxygen vacancy

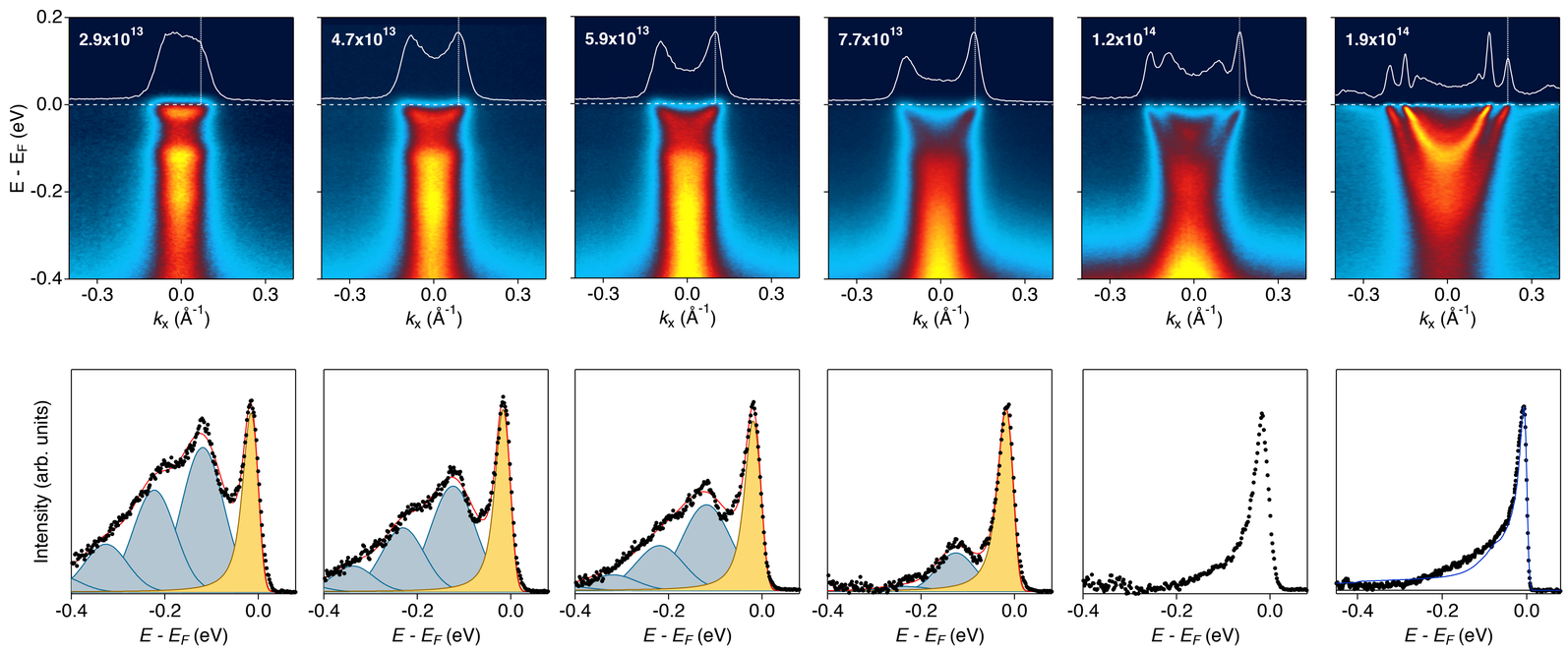




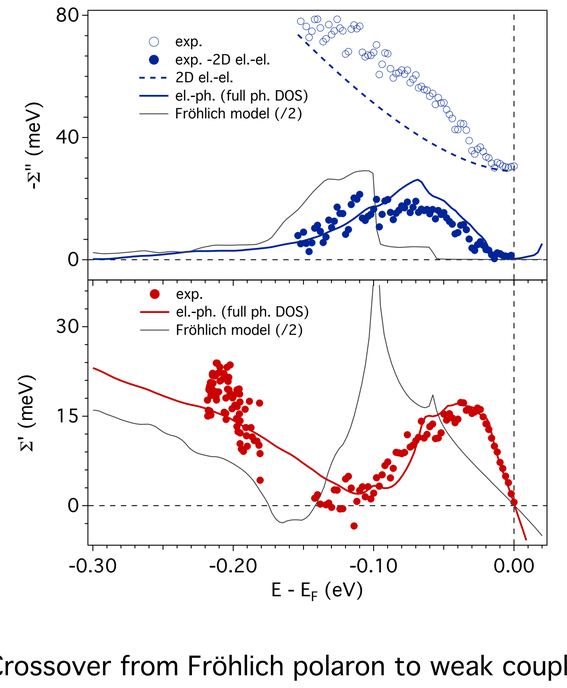


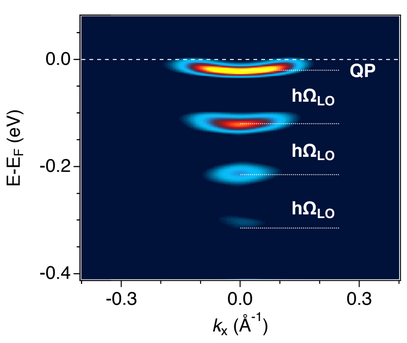
S. McKeown Walker *et al.*, Physical Review Letters, 113, 177601 (2014)
S. McKeown Walker *et al.*, Advanced Materials, 201501556 (2015)

A Two-Dimensional Gas of Large Polarons at Low Density

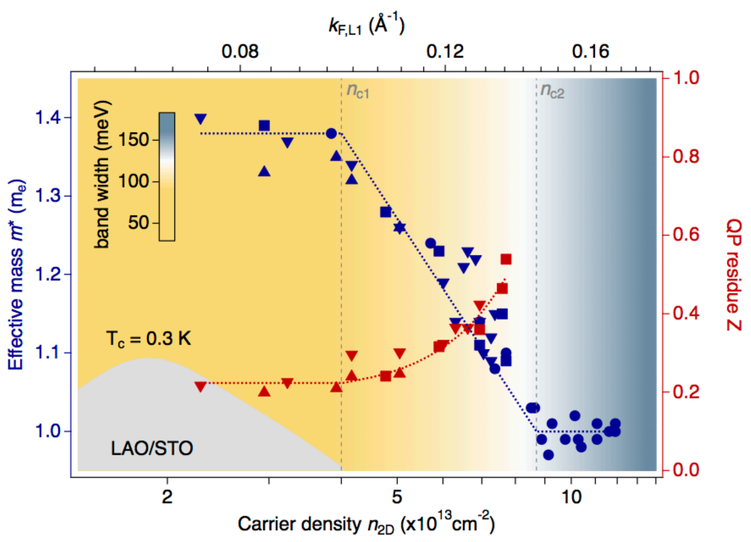


- At high density a kink is observed in the light subbands alongside a mass enhancement of the heavy subbands – self energies suggest more conventional el.-ph. coupling involving the entire phonon density of states
- Decreased coupling at high density is attributed to enhanced electronic screening





- Replica bands at 100 meV intervals below the main bands indicate strong long-range coupling to a single ~100meV LO phonon at low density
- Dispersive replica bands imply small q coupling, a hallmark of Fröhlich polarons
- Quasiparticle mass (m*) and the quasiparticle residue (Z) evolve with density



- Crossover from Fröhlich polaron to weak coupling with increasing density
- Onset of polaronic regime at $n_{2D} \approx 4 \times 10^{13}$ cm^{-3} coincides with onset of superconductivity at the $LaAlO_3/SrTiO_3$ interface

Z. Wang *et al., ArXiv 1506.01191* (2015)