k-dependence of the mass renormalisation in $Bi_2Sr_2CaCu_2O_{8+\delta}$:
a polarisation-dependent ARPES study

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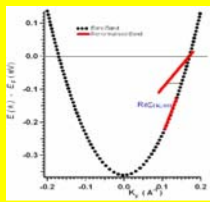
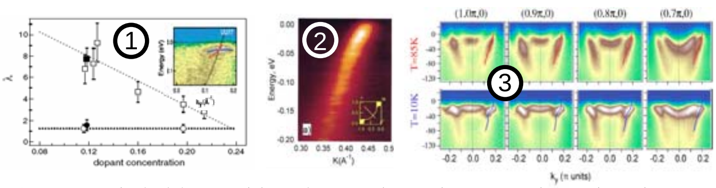
1. Introduction

We have used polarised Angle Resolved Photoemission (ARPES) to study the mass renormalisation around the Fermi surface in Pb-doped $Bi_2Sr_2CaCu_2O_8$.
This renormalisation is seen as a deviation of the E(*k*) dispersion of the independent particle band at low energy, close to the Fermi level.



Mass renormalisation: due to "dressing" of electron with interactions i.e. a coupling to collective, bosonic modes

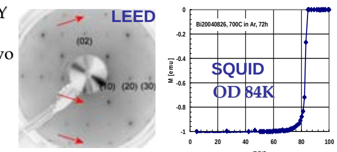


1). In Bi2212, the (π,0) (=antinodal point) renormalisation has a strong doping dependence
Kim *et.al*, PRL**91**,167002 (2003).
2). It shows doping dependences in the nodal direction (Bogdanov *et.al*, Valla *et.al*)
3). In OD 71, a momentum and temperature dependence was found near (π,0).
These measurements were from a sample with superstructure modulations
Gromko *et.al*, PRB**68**, 174520 (2003).

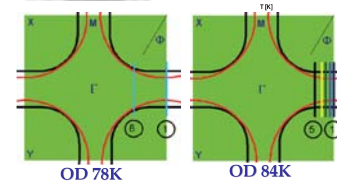
- ***What is the k-dependence of this renormalisation ?***
- ***Exploit variable polarisation to help distinguish the BB and AB bands***

2. Experimental

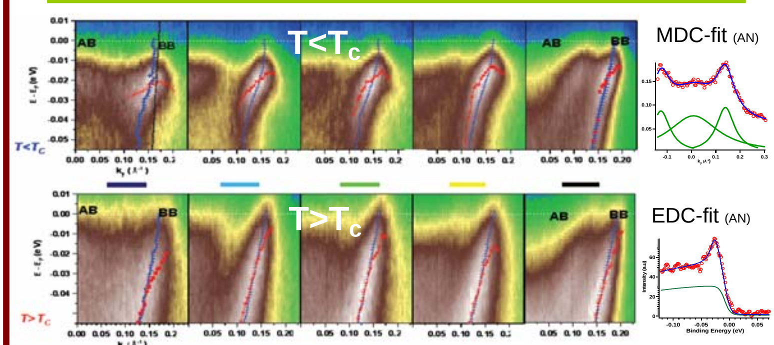
- SIS beamline X09LA at SLS and U125-1/PGM at BESSY
- SES2002 (SLS) and SES-100 (IFW Dresden@BESSY)
- hν chosen as 39 eV: maximises contrast between the two c-axis split bilayer bands
- (Pb,Bi)-2212 single crystals (FZ) grown in Amsterdam Untwinned, modulation-free.
- Tc of these crystals: OD 78K, OD 80K, and OD 84K



- For OD 78 and 80K, data taken from 8 different cuts and using different polarisations:
  linear horizontal (LH)
  circular left (CL)
  circular right (CR)
  Cut 1 represents antinode (AN), cut 8 is 7° away
- For OD 84K, 5 cuts are taken using LH radiation. Cut 1 = AN and cut 5 is 6° away from AN.



3. Results and data analysis: OD 84K

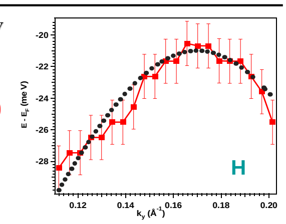


- Peak position in EDM shows band dispersion. EDC (red) dispersion more sensitive to the presence of the gap compared to the MDC (blue) dispersion.
- MDC dispersion is fitted using simple Lorentzian while EDC is fitted using Lorentzian multiplied by the Fermi-Dirac distibution, including a scaled background from k > k_F.
- Data clearly resolve the bilayer splitting

- EDC (red) dispersion can be approximated by a Bogolubov quasiparticle dispersion in the presence of the gap:

$$E(k) = \sqrt{m(k-k_F)^2 + \Delta^2} \quad \text{where} \quad m = \frac{v_F^b}{(1+\lambda)} \qquad (1)$$

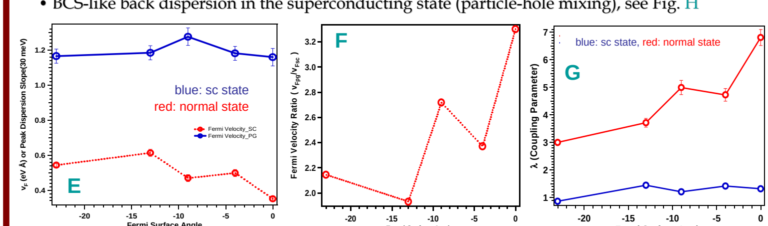
- Eq.1 works well at weak coupling regime. At strong coupling regime, the energy gap is similar to mode energy. It needs more complex expression (Fink *et.al* CM/0512307)



- The bare Fermi velocity can be obtained from the LDA data for the separation between bottom of the bonding (BB) and antibonding (AB) bands, given the experimental k_F for the BB:

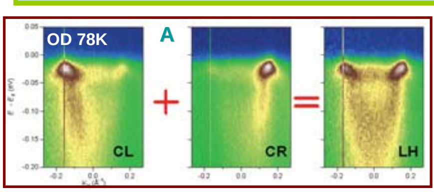
$$\varepsilon^b(k) = \frac{\varepsilon_{BottB}\,(k^2 - k_F^2)}{k_F^2} \qquad (2)$$

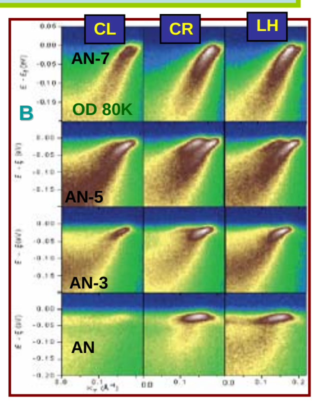
- The slope of (2) at low energy is bare velocity
- BCS-like back dispersion in the superconducting state (particle-hole mixing), see Fig. H



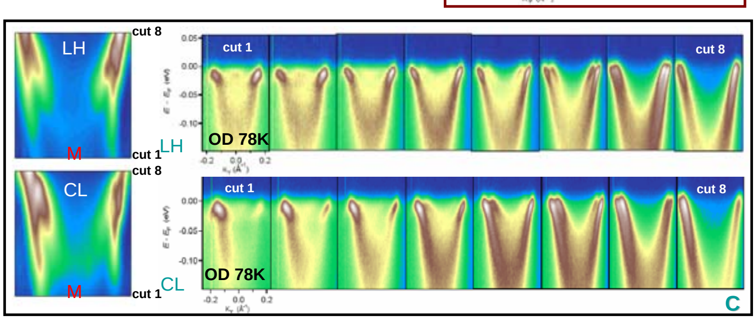
- Trend: for T above Tc, the slope is constant (E).
- Trend: degree of renormalisation (seen as the slope change) in the superconducting state decreases as we go from the antinode half-way towards the node (E and F)
- The coupling constant change on leaving the sc state decreases as we move from antinode towards the nodal line (G), while it is more like constant at T above Tc (G).

4. Results and data analysis OD 78K & 80K: polarisation-dependence





- Panel (A): CL and CR each pick out one side of the (0,0)-(π,0) line.
  The LH Spectra is very close to the sum of CL + CR.
- Panel (B): zoom of positive k_y side of the spectra for LH, CR, CL polarisations from AN to 7° towards the node.
  Trend : CR favours AB band, CL the BB. LH is in between.



- Panel (C): Momentum dependence of renormalisation for LH and CL polarised radiation.
  The degree of renormalisation is maximal at the AN and decreases as one moves away from the AN.
- Conclusions from panels B and C: exploiting circular light enables better resolution of the c-axis bilayer splitting. Multiple EDM's per cut make MDC and EDC fitting more robust.

This polarisation dependent data is still under analysis.

5. Conclusions

- The mass renormalisation for the bonding band for T<T_c is significantly momentum dependent:
  It is maximal at the antinodal point, decreasing steadily as one goes towards the node. This *k*-dependence practically vanishes for T above Tc.
- Use of circular polarised radiation offers bright prospects for improved BLS contrast in the tricky zone between the antinode and node.

With support from: FOM, Faculteit der Natuurwetenschappen, Wiskunde en Informatica, Van der Waals-Zeeman Instituut

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