Experimental report

12/09/2022

Proposal: **4-02-609**

Council: 4/2021

Title: Magnetic fluctuations and spin resonance peak in superconducting Nickelates

Research area: Physics

This proposal is a resubmission of 4-02-589

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Samples: $Sr_{0.2}Nd_{0.8}NiO_2$

Instrument	Requested days	Allocated days	From	To
IN5	7	0		
IN8 Flatcone	5	0		
PANTHER	7	3	06/09/2021	09/09/2021

Abstract:

In 2019, superconductivity has been surprisingly reported at 15 K in Sr-doped $NdNiO_2$ ($Nd_{0.8}Sr_{0.2}NiO_2$), suggesting the existence of a new family of high-temperature superconductors. The structure of this nickel oxide consists in a stacking of NiO_2 layers separated by rare-earth spacer layer, stabilizing the unusual Ni^{1+} oxidation state, corresponding to $3d^9$ electronic configuration similarly to the cuprates where high-temperature superconductivity is assumed to be due to spin fluctuations. In a collaboration with Alain Demourgues and Baptiste Vignolle at Institut de Chimie de la Matière Condensée de Bordeaux (ICMCB), we are currently synthesizing Sr-doped $NdNiO_2$ polycrystalline powder compounds. We propose to look for magnetic fluctuations and possible spin resonance peak using time-of-flight spectroscopy (IN5) for a sample with a Sr concentration of 20% where superconductivity is expected.

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Magnetic fluctuations and spin resonance peak in superconducting Nickelates

** Scientific case*

In 2019, superconductivity has been surprisingly reported at 15 K in Sr-doped $NdNiO_2$ ($Nd_{0.8}Sr_{0.2}NiO_2$), suggesting the existence of a new family of high-temperature superconductors. This compound presents an infinite-layer structure obtained after CaH_2 reduction of a 3D perovskite, $Nd_{0.8}Sr_{0.2}NiO_3$. The structure of this nickel oxide consists in a stacking of NiO_2 layers separated by rare-earth spacer layer, stabilizing the unusual Ni^{1+} oxidation state, corresponding to $3d^9$ electronic configuration. Chemically, this is achieved by a topotactic reaction. The existence of a superconducting phase in nickel oxides with this valence state was predicted twenty years ago in $LaNiO_2$ but was never achieved before. In this Nickelate, superconductivity arises after La atoms were replaced by Nd, smaller ions, making the material more conductive. Interestingly, the superconducting phase only occurs in the hole-doped phase and not in the parent compound, which remains a robust insulator. Even if the superconductivity is present still at quite low temperature, between 9-15K, the similar structure and electronic configuration, $3d^9$, compared to the Cuprates makes the discovery of superconductivity in Nickelates a major breakthrough. The finding of superconductivity in a compound that is structurally similar to these copper oxides may challenge the role of magnetism in the mechanism of unconventional superconductivity in all these high-Tc superconductors.

** Experiment #4-02-609*

In order to clarify the existence of spin fluctuations, we investigated the magnetic inelastic spectrum in Sr-doped $NdNiO_2$ polycrystalline samples. Powder samples were synthesized and characterize by powder X-ray diffraction. Magnetic susceptibility measurements on each sample were performed prior to the neutron experiment. Experiments on PANTHER were carried out on two samples: (i) pure $NdNiO_2$ taken as reference sample, (ii) 5%Sr-$NdNiO_2$ .The samples were installed in an orange cryostat on PANTHER. Measurement were performed with an incident energy E_i of either 76 meV or 19 meV. For data analysis, data were systematically divided by the sample mass, the signal from the empty can was subtracted and data were normalized by vanadium. Figures 1 and 2 report the scattered intensities, corrected by the Bose factor, for the pure pure $NdNiO_2$ sample and 5%Sr-$NdNiO_2$, respectively. The measurement at E_i=19 meV and 76 meV highlight signals at several energies, as illustrated by figure 3 at 1.5 K. The energy with of the observed signal can be compared to the energy resolution of instrument.

In data taken at E_i=19 meV, on observed two modes at 100 K in both samples: (i) a strong one at 13.5 meV and (ii) a weaker at 9.5 meV. On Cooling down to 5 K, the signal becomes stronger as expected of magnetic signal. The second signal is still visible, even if it remains rather weak.

In data taken at E_i=76 meV, one can identify three excitations at 1.5 K in the pure $NdNiO_2$. They are located at ~13.5 meV, ~22 meV and ~30 meV. It is worth noticing that in Nd_2CuO_4, crystal filed excitations appear at 15meV, 21 meV and 27 meV. Owing the similarity between the crystal structures of such material, one could ascribed the three observed modes to crystal excitation in pure. In the 5% substituted sample (Fig. 4) , these crystal field excitations seem weakly renormalized to ~14 meV, ~24 meV and 31 meV. One can nevetherless notice that the high mode close to 30 meV become hardly visible at 100 K. Furthermore, at variance with data in the pure sample, it seem that a fourth mode can be seen at 37 meV.

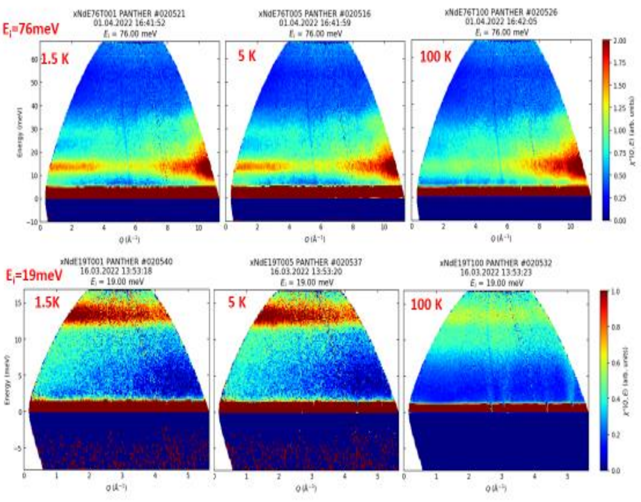

Fig. 1 : pure $NdNiO_2$

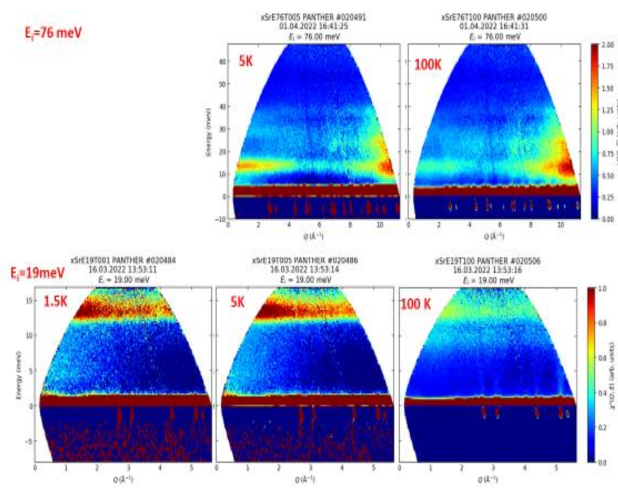

Fig. 2: 5%Sr-$NdNiO_2$,

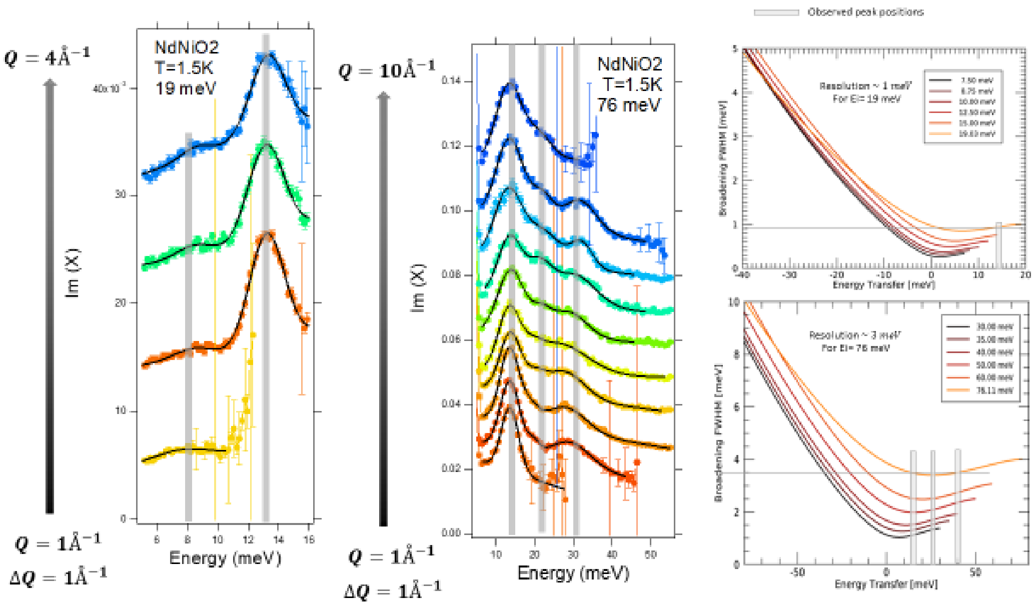

Fig. 3 : pure $NdNiO_2$: series of constant Q-scans a T=1.5 K for E_i=1.9 meV and 76 meV. The associated E-resolution is given I n the right panel .

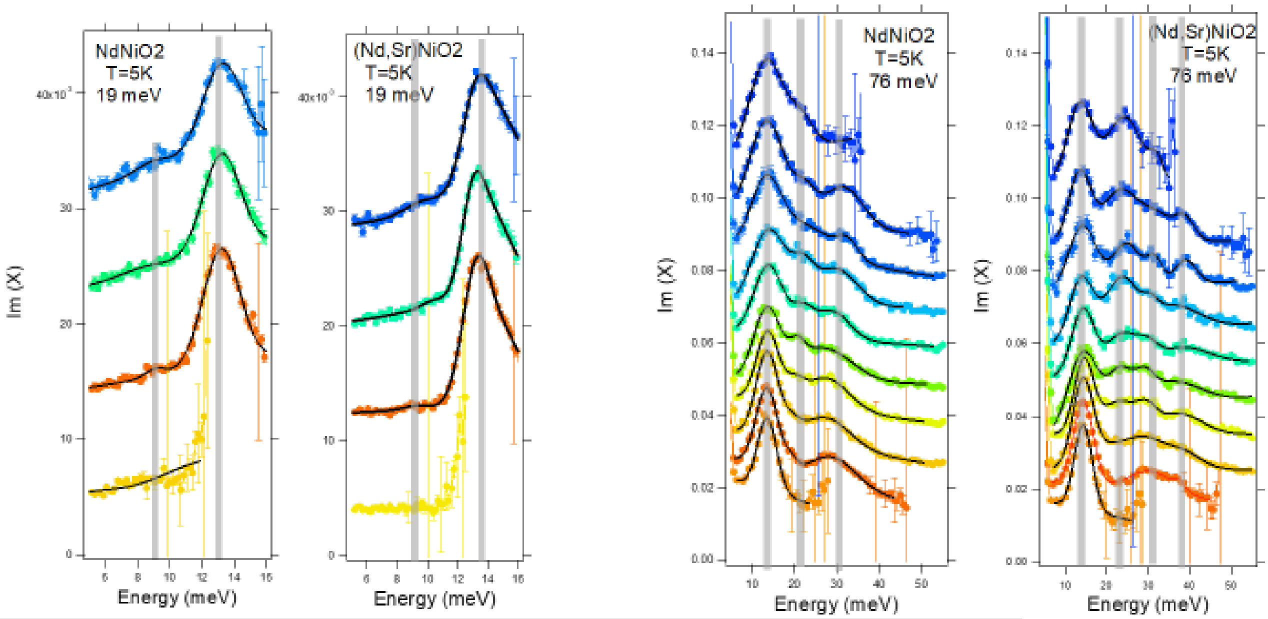

Fig.3: Q-Scans at 5 K in pure NdNiO2 and (Nd,Sr)NiO2 samples with Ei=19 meV and Ei=76 meV

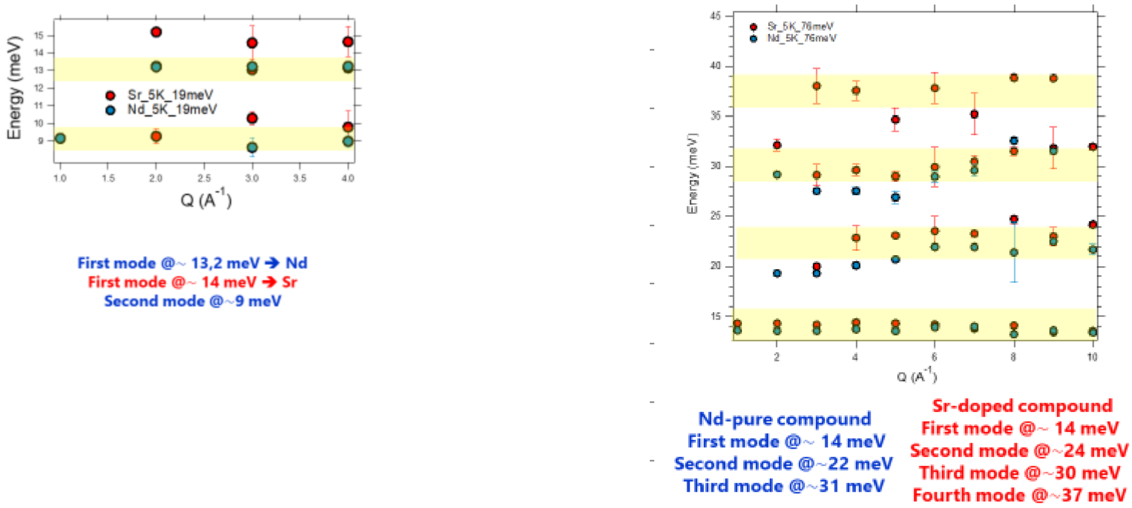

Fig.4: magnetic mode energies in pure NdNiO2 and (Nd,Sr)NiO2 samples with Ei=19 meV and Ei=76 meV