Fast-feedback R&D strategy for LMO scintillating crystals in neutrinoless Double Beta Decay search

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In recent years, scintillating materials have been employed in the development of the most advanced detectors for the search for rare events in particle physics, especially in the quest for dark matter and neutrino physics. A possible approach to indirectly measure the neutrino mass [1] is through the search for the neutrinoless Double Beta Decay ($0\nu\beta\beta$). In this case, one of the most promising technologies relies on scintillating cryogenic calorimeters operating at mK temperatures [2]. These detectors measure simultaneously the energy deposited in the form of phonons (heat) and the amount of emitted scintillation photons (light) by each particle interaction and rely on the ratio of the two channels for the background rejection. One of the next-generation experiments based on this technology is the CUPID (CUORE Upgrade with Particle IDentification) experiment at Gran Sasso National Laboratories, which will be built with ~ 450 kg of Li_2MoO_4 (LMO), organized in ~ 1600 scintillating crystals. The crystals will be enriched with ^{100}Mo to ~ 95 % which spontaneously decays via $\beta\beta$.

Despite the promising performance of this dual readout approach, the detector sensitivity would significantly be improved by an increase in the LMO crystal light yield. A first unsuccessful attempt was carried out by growing Ag-doped crystals to try to introduce a more efficient luminescent centre [3]. Unfortunately, R&D carried out using single crystals is extremely expensive and time consuming making the process inefficient. A possible alternative strategy would be to synthetize small amounts of LMO crystalline powders by a fast chemical route. However, considering the relevant role of point defects in the scintillation performances of LMO, as proved in a recent paper [3], it is important that the scintillation properties and defects formation in the powders are similar to those observed in single crystals. This would make the investigation relying on powders meaningful and we could expect to transfer its achievements to the case of single crystals grown by conventional techniques.

In this work we synthetize undoped LMO crystalline powder using a solid state reaction starting from Li_2CO_3 and MoO_3, mixing and treating at 550 °C for 12 hours. A detailed structural and spectroscopic characterization is carried out on the powders and compared with previous results obtained on single crystals grown by the Czochralski technique. The study confirms the validity of this approach and justifies further investigation. New powder samples are synthetized doping LMO with transition and post-transition metals and the first results are presented.

1. R.N. Mohapatra, et al., "Theory of neutrinos: a white paper", *Rep. Prog. Phys.* **70** (2007) 1757–1867
2. D.Q. Adams, et al., "Search for majorana neutrinos exploiting millikelvin cryogenics with CUORE", *Nature* **604**, 53–58 (2022).
3. F. Cova, et al., "Effect of point defects on the performances of Li_2MoO_4 and Li_2WO_4 crystals as scintillating cryogenic calorimeters", *Journal of Alloys and Compounds* **1022**, 179848 (2025).