

# Quantum Anomalous Hall Effect applied to metrology: the EPM project QuAHMET

Giuseppe Maruccio<sup>1,2</sup>, Martina Marzano<sup>3</sup>, Luca Callegaro<sup>3</sup>, Stephen Giblin<sup>4</sup>, Charles Gould<sup>5,6</sup>, Thorsten Hesjedal<sup>7</sup>, Johannes Hoffmann<sup>8</sup>, Nathaniel Huang<sup>4</sup>, Nobu Kaneko<sup>9</sup>, Olga Kazakova<sup>4</sup>, Mattias Kruskopf<sup>10</sup>, Jan Kuřera<sup>11</sup>, Sayani Majumdar<sup>12</sup>, Laurens W. Molenkamp<sup>5,6</sup>, Mehmet Cengiz Onbasli<sup>13,14</sup>, Frédéric Overney<sup>8</sup>, Ayşe Gökçe Özbay<sup>15</sup>, Martino Poggio<sup>16</sup>, Hansjörg Scherer<sup>10</sup>, Susmit Kumar<sup>17</sup>

- <sup>1</sup> *Università del Salento, Italy*
- <sup>2</sup> *CNR-Nanotec, Italy*
- <sup>3</sup> *INRIM Istituto Nazionale di Ricerca Metrologica (INRIM), Italy*
- <sup>4</sup> *NPL Management Limited, United Kingdom*
- <sup>5</sup> *Faculty for Physics and Astronomy (EP3), Universität Würzburg, Germany*
- <sup>6</sup> *Institute for Topological Insulators, Germany*
- <sup>7</sup> *University of Oxford, United Kingdom*
- <sup>8</sup> *METAS Eidgenössisches Institut für Metrologie, Switzerland*
- <sup>9</sup> *AIST National Institute of Advanced Industrial Science and Technology, Japan*
- <sup>10</sup> *PTB Physikalisch-Technische Bundesanstalt, Germany*
- <sup>11</sup> *CMI Cesky Metrologický Institut, Czech Republic*
- <sup>12</sup> *Tampereen korkeakoulusäätiö sr, Finland*
- <sup>13</sup> *Department of Electrical and Electronics Engineering, Koç University, Turkey*
- <sup>14</sup> *Department of Physics, Koç University, Turkey*
- <sup>15</sup> *TUBITAK Türkiye Bilimsel ve Teknolojik Arastırma Kurumu, Turkey*
- <sup>16</sup> *Universität Basel, Switzerland*
- <sup>17</sup> *JV National Laboratory, Justus-Liebig-Universität, Germany*

Quantum Anomalous Hall Effect | metrology |

**Abstract:** The aim of the Joint Research Project QuAHMET (Quantum Anomalous Hall Effect Materials and Devices for Metrology) is to investigate and implement novel technologies for the development of quantum anomalous Hall effect (QAHE) devices and measurement systems for metrology. The project consortium involves national metrology institutes (NMIs) and academic institutions from Europe and Asia, counting fourteen partners from nine different countries. It is funded with an EU contribution of about 1.3 M€ and will run from 2024 to 2027. Primary resistance standards currently employed in metrology are currently based on quantum Hall effect devices requiring very low temperature and high magnetic fields to operate. The QAHE is a good candidate to simplify the realization of the resistance unit and the development of a 'quantum electrical metrology toolbox' for universal adoption of quantum electrical SI standards, beyond the only NMIs. The project will mainly focus on the improvement of the growth techniques of magnetically doped topological insulator (TI) optimising the material properties for the QAHE, the investigation of electronic, structural, magnetic, and magneto-electronic properties of the samples, and of the limitation conditions of QAHE (especially temperature and current), by employing also scanning probes and magnetometry techniques at low temperatures. The NMIs involved will be in charge of the development and application of accurate measurement techniques to perform a detailed metrological assessment of the optimised QAHE devices, both at sub-Kelvin and above 1 K temperatures, at currents above 1  $\mu$ A and at low-to-zero applied magnetic field. The project aims to connect with and impact on NMIs and calibration centers, academia, T&M industry and end users interested in applications, such as spintronics and topological quantum computing and advance the research and progress in the field of TIs. A stakeholder committee is being set up and a periodic newsletter will be distributed. A website, social media groups and channels, and newsletters are under construction and will be running by the time of the presentation. Acknowledgement: The project 23FUN07 QuAHMET has received funding from the European Partnership on Metrology, co-financed from the European Union's Horizon Europe Research and Innovation Programme and by the Participating States.

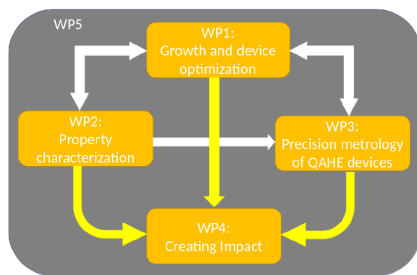


Fig. 1. Graphical representation of the interaction between the five work-packages of the project.

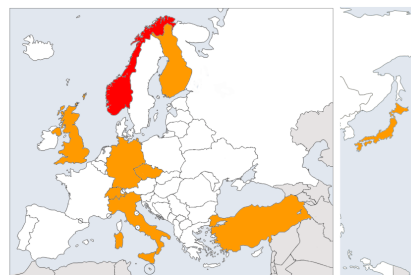


Fig. 2. Map of the project partners.