1 Explanation of the work carried out

Task number & title *excluding the uptake and exploitation task (JRPs & JNPs only) & management & coordination tasks*	Task end date in Annex 1	Actual task completion date	Status: *inactive, on schedule, delayed to..., or completed*	Explanation of the work carried out in each task in this reporting period	
				Summary of the progress towards the aim of each task in this reporting period (max 700 words per task)	**Explain any issues affecting the completion of the tasks (eg describe the cause of delays / deviations etc. and any knock-on effects)** (max 300 words per task)
2.1: Quantum sensing facility and techniques	May 2024		On Schedule	**Activity A2.1.1** The activity is **complete.** The facility for electromagnetic field sensing is equipped with a single-photon sensitive confocal microscope (compatible with ODMR measurements), lock-in amplifiers, Helmholtz coils, and pulsed excitation. Preliminary Lock-in testing and pulsed ODMR measurements have been performed demonstrating Rabi oscillation and pulsed ODMR. The facility for electromagnetic field sensing using single-atom like sensors in diamond is ready for use. **Activity A2.1.2** Activity started. Preliminary optimisation of detection methods for shot noise limited signal detection and common mode rejection in DTU setup. Collaboration on Lorentzian line-fitting. DTU and DFM started the design of fluorescence detectors with low electronic noise and high saturation power. Optimized self-balanced detector for DTU constructed at DFM for optimized common mode rejection. The activities to assist DTU with detection related issues will run throughout the project period. **Activity A2.1.3** The activity to develop EM-noise-insensitive temperature measurement techniques is **complete**. The EM insensitive temperature measurement technique has been demonstrated (2x sensitivity achieved). **Activity A2.1.4** The activity has started and is ongoing. Using Floquet theory, DTU has designed and implemented optimal control pulses, increasing contrast and sensitivity in \pi-pulse ODMR by ~20% compared to standard square modulation. Other modulation forms tailored to inhomogeneous spin and bath distribution are being tested further. Results on protocols for the sensing in the 10kHz – 2MHz regime, target resolution of ~1kHz, expected in May-June. **Activity A2.1.5** Not started.	**A2.1.5** The previously reported delay in activity 2.1.1 due to limited access to the labs under COVID-19 restrictions (now completed affected this activity)The optical detection system developed in A4.3.1 and to be used in this activity was completed in M18 and preliminary discussions on the joint activity between INRIM and CMI started immediately afterwards

2.2: NV sensor characterisatio n	May 2024		On Schedule	**Activity A2.2.1** The activity has started ahead of schedule. Different diamond crystals (a commercial optical grade diamond crystal, a highly N-doped and ^{12}C-enriched diamond crystal and an electron-irradiated and annealed HPHT diamond crystal) were compared in terms of magnetic sensitivity using a wide field NV DC-magnetometer. Other diamond crystals from QADeT partners could also be investigated. We observe a better sensitivity due to higher NV concentration. The same sensitivity is obtained for highly doped CVD and HPHT crystals. The higher NV concentration of HPHT sample is compensated by the narrower ODMR linewidth resulting from ^{12}C doping. **Activity A2.2.2** Activity **completed** ahead of schedule. Two sensors have been characterized using the decoupling techniques achieved in A2.1.3. As an optimal sensing parameter, the dependency and the temperature sensitivity as a function of the optical excitation power was investigated. Those parameters for the two samples were compared in function of the material properties (NV concentration, sensing volume). **Activity A2.2.3** Not started. **Activity A2.2.4** The activity has started ahead of schedule. The reference sensor at DTU is operating with a sensitivity routinely <100pT Hz^-1/2. Discussions are in progress between DTU and DFM on the DFM detector to test. We will then explore the sensitivity limits, characterize dynamic range, linearity and bandwidth. Results expected also in May/June. **Activity A2.2.5** Not started	**A2.2.5** This activity depends on the completion of A1.1.5 which is delayed.
2.3: NV sensor proof-of-principle application	May 2024		On Schedule	**Activity A2.3.1** We have performed an in-depth characterization of the NV spectrum analyser using our available 110 oriented E6 sample. The achieved performances are a range of 27 GHz, a bandwidth up to 4 GHz, a frequency resolution of a few MHz, a temporal resolution of a few ms and a dynamic range of 30 dB. The results have been published in the Nature group: S. Magaletti et al., Comm. Eng. 1, 19 (2022), https://doi.org/10.1038/s44172-022-00017-4. **Activity A2.3.2** Not started. **Activity A2.3.3** The activity started ahead of schedule and some preliminary results were already described in the M9 report. On NV centers, we measured ODMR signals of NV centers at pressures up to 130 GPa. The contrast of the spin resonance was kept almost constant compared to ambient pressure by engineering a quasi hydrostatic stress environment for the	

				NV centers located on the tip of the anvil. Hydrostatic compression was obtained by milling a micro-pillar in the tip. The micro-pillar is then immersed in the pressure transmitting medium that is squeezed between the two flattened tips of the anvils and the metallic gasket of the diamond anvil cell. These results are described in a paper that was submitted on 12 January 2023 (arXiv:2301.05094) and is now under review. On SiV and GeV centers, the work during this second period of the project was focused on preparing and submitting a publication (arxiv:2209.09792, submitted on 20 Sep 2022). This task led to a careful comparison between the experimental results and the computed evolution of the ZPL based on ab-initio methods. The paper has been now published (Phys. Rev. B 106, 214109, 19 December 2022), being highlighted as Editor's suggestion. **Activity A2.3.4 Completed ahead of schedule.** The activity has started ahead of schedule. Detection of action potentials from brain tissue has succeeded. The results clearly demonstrate the possibility to detect neuron action potentials from mammal brain tissue. Moreover, for the first time, temperature variations (1°K) associated with potentiation and inhibition of neuronal firing in a cultured mice hippocampal neurons was detected, by exploiting a nanoscale thermometer based on NV centers in NDs. **Activity A2.3.5** Not started.	