S4-13: Accurate operation of single-electron pumps beyond 1 GHz

Authors: M. Kataoka¹, S. P. Giblin¹, J. D. Fletcher¹, P. See¹, J. P. Griffiths², G. A. C. Jones², I. Farrer², D. A. Ritchie², M. –H. Bae³, Y.-H. Ahn³,⁴, M. Seo³,⁵, Y. Chung⁵, N. Kim³, G. Yamahata⁶, T. Karasawa⁶, A. Fujiwara⁶, R. Zhao⁷, A. Rossi², F. E. Hudson⁷, M. Möttönen⁸, A. S. Dzurak⁷, and T. J. B. M. Janssen¹

Affiliation of authors: ¹National Physical Laboratory, Hampton Road, Teddington, Middlesex, TW11 0LW, UK. ²Cavendish Laboratory, University of Cambridge, J J Thomson Avenue, Cambridge CB3 0HE, UK. ³Korea Research Institute of Standards and Science, Daejeon 34113, Republic of Korea. ⁴Department of Physics, Korea University, Seoul 136-713, Republic of Korea. ⁵Department of Physics, Pusan National University, Busan 609-735, Republic of Korea. ⁶NTT Basic Research Laboratories, NTT Corporation, 3-1 Morinosato Wakamiya, Atsugi, Kanagawa 243-0198, Japan. ⁷School of Electrical Engineering and Telecommunications, University of New South Wales, Sydney, New South Wales 2052, Australia. ⁸QCD Labs, COMP Centre of Excellence, Department of Applied Physics, Aalto University, 00076 AALTO, Finland.

Speaker: Masaya Kataoka

Speaker email: masaya.kataoka(at)npl.co.uk

Abstract: Semiconductor-based single-electron pumps are promising candidates to be used as primary standards for the revised ampere. These nanoscale devices transfer electrons one per cycle, generating a quantised current \( I = ef \), where \( e \) is the elementary charge and \( f \) is the pump operating frequency. Current quantisation accuracy as good as 1.6 parts in \( 10^7 \) has been demonstrated [1]. One of the remaining important challenges is to increase the pump current in order to reduce the measurement integration time. For this purpose, it is desirable to operate pumps at frequencies above 1 GHz, but it has been shown that the current quantisation accuracy tends to degrade rapidly in the high-frequency range. This means that a current plateau for a certain parameter sweep shows a finite slope, i.e., a varying current level, which contributes to the uncertainty in determining the value of current quantisation. To date, the uncertainty (in the flatness of the current plateau) achieved for ~1 GHz operation is ~1 part in \( 10^6 \) [1-5], which has been the limiting factor in achieving the current quantisation accuracy at the level of 1 part in \( 10^7 \) or better. Here, we will discuss the scope for improving the performance of single-electron pumps beyond 1 GHz, based on the recent results on GaAs and Si-based devices and a pump-error-reduction technique using arbitrary waveform generators.