Joint mass-and-energy test of the equivalence principle with atom interferometers

Ming-Sheng Zhan[1]

[1]*Wuhan Institute of Physics and Mathematics, Innovation Academy for Precision Measurement Science and Technology, Chinese Academy of Sciences, Wuhan 430071, China*

The equivalence principle (EP) is a basic assumption of the general relativity. Quantum test of EP with atoms is an important way to examine the applicable scope of the current physical framework, so as to discover new physics. Recently we improve the four-wave double-diffraction Raman transition method (4WDR) [1] we proposed before to select atoms with a certain mass and angular momentum state, and form a dual-species atom interferometer. By using the extended 4WDR to ^{85}Rb and ^{87}Rb atoms with specified mass and internal energy we carry out a joint mass-energy test of EP [2], which is a first step in joint tests of two attributes beyond the traditional pure mass or energy tests of EP with quantum systems. The violation parameter of mass is constrained to $\eta_0 = (0.8 \pm 1.4) \times 10^{-10}$, and that of internal energy to $\eta_E = (0.0 \pm 0.4) \times 10^{-10}$ per reduced energy ratio a ($a = h\nu_0/m_i^{85}c^2$, and $\nu_0 = 1$ GHz). In this talk, I will briefly outline the joint test idea and report the latest experimental progress towards higher precision mass-energy test of EP. We have observed atomic interference fringes of $2T$ = 2.6 s in the 10-meter long-baseline atom interferometer [3], and the corresponding resolution of gravity measurement is $4.5 \times 10^{-11} g$ per shot.

[1] Lin Zhou, Shitong Long, Biao Tang, Xi Chen, Fen Gao, Wencui Peng, Weitao Duan, Jiaqi Zhong, Zongyuan Xiong, Jin Wang, Yuanzhong Zhang, and Mingsheng Zhan, *Test of Equivalence Principle at 10^{-8} Level by a Dual-Species Double-Diffraction Raman Atom Interferometer,* **Phys. Rev. Lett. 115,** 013004 (2015).

[2] Lin Zhou, Chuan He, Si-Tong Yan, Xi Chen, Dong-Feng Gao, Wei-Tao Duan, Yu-Hang Ji, Run-Dong Xu, Biao Tang, Chao Zhou, Sachin Barthwal, Qi Wang, Zhuo Hou, Zong-Yuan Xiong, Yuan-Zhong Zhang, Min Liu, Wei-Tou Ni, Jin Wang, and Ming-Sheng Zhan, *Joint mass-and-energy test of the equivalence principle at the 10^{-10} level using atoms with specified mass and internal energy*, **Phys. Rev. A 104,** 022822 (2021).

[3] Ming-Sheng Zhan, Jin Wang, Wei-Tou Ni, Dong-Feng Gao, Gang Wang, Ling-Xiang He, Run-Bing Li, Lin Zhou, Xi Chen, Jia-Qi Zhong, Biao Tang, Zhan-Wei Yao, Lei Zhu, Zong-Yuan Xiong, Si-Bin Lu, Geng-Hua Yu, Qun-Feng Cheng, Min Liu, Yu-Rong Liang, Peng Xu, Xiao-Dong He, Min Ke, Zheng Tan, and Jun Luo, *ZAIGA: Zhaoshan Long-baseline Atom Interferometer Gravitation Antenna,* **Int. J. Mod. Phys. D 29,** 1940005 (2020).