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微纳技术与精密机械

微隧穿式陀螺仪检测模态的线性二次高斯控制

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摘要： 为了将微隧穿式陀螺仪(MTG)的隧尖与检测电极之间的隧道间隙及其变动量分别维持在1 nm和0.1 nm并降低系统噪声和扩大带宽,本文为其检测模态设计了线性二次高斯(LQG)闭环反馈系统。在利用微小量法对呈指数规律的隧道效应进行线性化的基础上,建立了MTG检测模态的线性化模型,并将哥氏加速度和电子隧道1/*f*噪声分别当作主要的过程噪声和输出噪声,设计了由最优状态估计器和线性二次(LQ)状态调节器组成的LQG控制器。搭建了仿真系统和实际的LQG控制电路并进行动态测试。仿真结果显示,LQG控制在将系统的信噪比提高24 dB的同时,能够将两个隧道电极之间的间隙的变动量控制在10^{-4} nm。实验曲线表明,隧道电流噪声的峰峰值为0.4 nA,LQG反馈控制系统在动态加速度信号的激励下可维持恒定隧道间隙为1 nm。

关键词： 隧道检测 陀螺仪 检测模态 线性二次高斯控制

LQG control for sensing mode of micro tunneling gyroscope

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Abstract: In order to maintain the tunneling gap and its fluctuation between a tunneling tip and a detecting electrode at the operation points of 1 nm and 0.1 nm respectively, a Linear Quadratic Gauss (LQG) closed-loop feedback control system was designed to reduce the system noise and to expand the bandwidth of the Micro Tunneling Gyroscope (MTG). Based on the linearization of the exponential tunneling effect using the minification method, the linearized model of the sensing mode of the MTG was deduced. By taking the Coriolis acceleration and electronic tunneling 1/*f* noise as the process noise and output noise of the sensing mode of the MTG, respectively, the LQG controller composed of a optimal state estimator and a Linear Quadratic (LQ)regulator was designed. The simulated system and the real LQG control circuit were established for the dynamic test. The simulation results show that the signal-to-noise ratio can be increased by 24 dB and the deviation of the tunneling gap between the two electrodes can be maintained at the value of 10^{-4} nm by the proposed LQG feedback controller.Furthermore, the testing curve indicates that the peak-to-peak amplitude of the tunneling current noise is 0.4 nA and the tunneling gap can be controlled to be 1 nm under the excitation of dynamic acceleration.

Keywords: tunneling detection gyroscope sensing mode Linear Quadratic Gauss(LQG) control.

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