专题:近地表地下空间地球物理精细探测技术

电替代绝对辐射计及地球辐射探测应用展望

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摘要:太阳辐射经地表反射、大气散射等物理过程被赋予丰富的光学信息,在时间序列上空间解析的观测太阳入射辐射、地球反射和发射辐射,可为气候气象、地球辐射收支、资源探测、陆地环境、海洋水色等研究提供科学依据。电替代测量原理已诞生100多年,是实现光辐射绝对测量的主要途径。电替代绝对辐射测量的核心是宽谱段、高吸收比的腔型热电型探测器,入射光经过多次反射、吸收转化为温升,当该温升被电加热复现,可通过精确测量电功率来标定入射光功率,测量结果可直接溯源至国际基本单位制(SI)中的电流。电替代绝对辐射计具备可溯源、高稳定等技术优势,广泛应用于太阳辐射测量、辐射计量、光学遥感等领域。伴随遥感卫星技术发展,电替代绝对辐射计成功应用于空间太阳入射辐射测量,通过多项校正因子修正后测量不确定度达到0.2%,风云三号系列太阳辐射监测仪自2008年获得并共享连续、精准的太阳总辐照度监测数据。采用真空、制冷、超导等技术,低温4~20K运行的电替代绝对辐射计将测量不确定度提升至0.03%,成为目前世界公认的光辐射计量标准。针对星上高精度辐射测量与溯源的难题,基于空间低温绝对辐射计建立星上辐射基准是国际公认的解决途径,利用交叉定标实现光学遥感卫星辐射标度的在轨溯源,将跨越式提升可见近红外波段地球反射光谱辐射测量精度及长期稳定度。为满足地球反射和发射辐射测量需求,电替代绝对辐射计需要攻克平面型探测器、高吸收比涂黑工艺等关键技术,弥补响应时间长的缺点,快速响应的平面型电替代绝对辐射计可实现短波、长波和全波辐射测量,在空间精准监测地球辐射能量不平衡真值的研究中发挥重要作用。

关键词:电替代;辐射测量;光学遥感;太阳总辐照度;辐射收支

Electrical substitution absolute radiometer and application prospect of earth radiation detection

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Abstract: Solar radiation is endowed with abundant optical information by surface reflection, atmospheric scattering and other physical processes. The spatially analytical observation of solar incident radiation, earth reflection and emission radiation in time series can provide scientific basis for the study of climate and meteorology, earth radiation budget, resource exploration, land environment, ocean color and so on. The principle of electrical substitution measurement has been born for more than 100 years, which is the main way to realize the absolute measurement of optical

radiation. The core of absolute radiation measurement with electrical substitution is a wide spectral band and high absorption ratio cavity thermoelectric detector. The incident light is converted into temperature rise after multiple reflection and absorption. When the temperature rise is reproduced by electric heating, the incident light power can be calibrated by accurately measuring the electric power, and the measurement results can be directly traced to the current in the international system of basic units (SI). With the technical advantages of traceability and high stability, electrical substitution absolute radiometer is widely used in solar radiation measurement, radiometry, optical remote sensing and other fields. With the development of remote sensing satellite technology, the electrical substitution absolute radiometer has been successfully applied to the measurement of solar incident radiation in space, and the measurement uncertainty has reached 0.2% after correction by a number of correction factors. Since 2008, the FY-3 series solar irradiance monitors have obtained and shared continuous and accurate total solar irradiance monitoring data. Using vacuum, refrigeration, superconductor and other technologies, the electrical substitution absolute radiometer operating at low temperature of 4～20k will increase the measurement uncertainty to 0.03%, which has become the world recognized standard for optical radiation measurement. Facing to the problem of high-precision radiation measurement and traceability on satellite, it is an internationally recognized solution to establish the radiation benchmark based on space cryogenic absolute radiometer. The cross calibration is used for realizing on orbit traceability of optical remote sensing satellite radiation scale. Then the accuracy and long-term stability of visible and near-infrared earth reflection spectrum radiation measurement will be greatly improved. In order to meet the needs of the earth's reflection and emission radiation measurement, the electrical substitution absolute radiometer needs to overcome the key technologies such as planar detector, high absorptivity blackening process and so on, to make up for the shortcomings of long response time. The fast response planar electrical substitution absolute radiometer can realize short wave, long wave and full wave radiation measurement, which can play an important role in the research of accurately monitoring the earth's radiation energy imbalance in space.

Keywords: Electrical substitution; Tadiometry; Optical remote sensing; Total solar irradiance; Radiation budget