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HIGH RESOLUTION NANO-SATELLITE IMAGERY: LIGHT-WEIGHT AND LOW-COST SYSTEM DESIGN USING MEMBRANE OPTICS

Abstract

Distributed systems are a common place in the current day, following the trend of such decentralization in every technology, we envision space technology becoming available to every individual through ubiquitous deployment of nano-satellites. Replacing one large-satellite with multiple small satellites would be cost effective while achieving finer spatial and temporal resolutions and a myriad of other benefits implicit to distributed systems. Imaging in various modalities forms the core of the satellite payloads. Conventional satellite systems employ a reflective/refractive based imaging systems, however, such systems are often bulky and may not suit the requirements of nano-satellites. Therefore developing novel image acquisition modalities suitable for small and light payloads assumes significance. In this context, we propose to use an imaging system based on diffractive optics that can address the size and weight constraints of conventional optics. A foldable low-cost light-weight membrane is used as a prime component of the proposed system which would provide various cost-benefits and eliminates the need for carrying heavy payload for nano-scale satellites.

At the heart of such an optical system lies a photon sieve, which is fabricated by etching millions of pinholes of suitable dimension at appropriate locations. The phase of the light passing through these holes get altered and the desired intensity profile can be achieved. Though the maximal efficacy of such a sieve is only 40% (amount of light that can pass through the sieve), focusing parameters are optimized by tuning the positions and dimension of the holes to provide on-par resolution over conventional optics.

Indian Institute of Technology Hyderabad's Student Satellite Project (IITHSSP) proposes to use such a photon sieve in a nano-satellite to demonstrate the feasibility of the membrane optics for next generation satellite imaging needs. Our system intends to capture images of the earth with a resolution of approximately 5 square-meters and can cover an area larger than 100 square-kilometers. The present work aims at characterizing the sieve to optimize the intensity distribution through the choice of hole-pattern. Further, various materials that suit the membrane requirements are investigated. Specifically, we propose to use Polyimide/PMMA like materials with low co-efficient of thermal expansion to overcome the temperature fluctuations and suit space requirements. In this paper, we provide a tradeoff among image resolution against system-weight and demonstrate the utility of membrane optics over conventional optical systems and test results of suitable membrane materials.