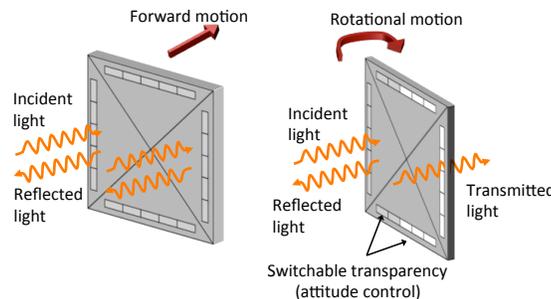


Propellantless Attitude Control of Solar Sail Technology Utilizing Reflective Control Devices

Steering a Spacecraft with Light

Solar sails offer an opportunity for a CubeSat-scale, propellant-free spacecraft technology that enables long-term and long-distance missions not possible with traditional methods. Solar sails operate using the transfer of linear momentum from photons of sunlight reflected from the surface of the sail. To propel the spacecraft, no mechanically moving parts, thrusters, or propellant are needed. However, attitude control, or orientation, is still performed using traditional methods involving reaction wheels and propellant ejection, which severely limit mission lifetime. For example, the current state of the art solutions employed by upcoming missions couple solar sails with a state of the art propellant ejection gas system. Here, the use of the gas thruster has limited the lifetime of the mission. To solve the limited mission lifetime problem, the Propellantless Attitude Control of Solar Sail Technology Utilizing Reflective Control Devices project team is working on propellantless attitude control using thin layers of material, an optical film, electrically switchable from transparent to reflective. The technology is based on a polymer-dispersed liquid crystal (PDLC), which allows this switch upon application of a voltage. This technology removes the need for propellant, which reduces weight and cost while improving performance and lifetime.

In order to perform attitude control without propellant, the solar sail's reflectivity is switched, which enables the modification of light photon pressure on the sail and hence control attitude (see Figure 1). This process is performed using a PDLC that has micron-sized liquid crystal droplets that are embedded within a polymer matrix. In the 'off' state, the liquid crystal droplets are randomly oriented. This random orientation causes a variation in how the light is bent (index of refraction) upon entering the solar sail, which leads to diffuse reflection (similar to white paint). In the 'on' state, the liquid crystals are aligned with the electric field, and the falling light sees no variation in the index of refraction, thus, the light is transmitted. The project team has developed and fabricated PDLC devices that can be easily



Schematic of solar sail with propellantless attitude control based on switchable films.

switched between reflective and transparent states, leading to a proposed three times improvement in the momentum change of the sails compared to other optical switching devices based only on reflectivity changes (no transmission).

This work addresses the current needs in attitude control for solar sails, which are planned for CubeSat missions. The proposed technology has a direct pipeline for mission infusion into upcoming solar sail projects. NASA is currently investing in attitude control capabilities for solar sailing missions, and the ability of the solar sail to not only provide propulsion for future science missions but also to reduce mass and volume by performing its own attitude control has proven very desirable. As NASA continues to invest in solar sailing missions, this capability is greatly needed.

This project is a collaboration between researchers at the University of Maryland in College Park, NASA's Marshall Space Flight Center and NASA's Langley Research Center located in Huntsville, Alabama and Hampton, Virginia, respectively.

NASAfacts

The project is funded through the SmallSat Technology Partnerships, a program within the Small Spacecraft Technology Program (SSTP). The SSTP is chartered to develop and mature technologies to enhance and expand the capabilities of small spacecraft with a particular focus on communications, propulsion, pointing, power, and autonomous operations. The SSTP is one of nine programs within NASA's Space Technology Mission Directorate.

For more information about the SSTP, please visit: <http://www.nasa.gov/smallsats>

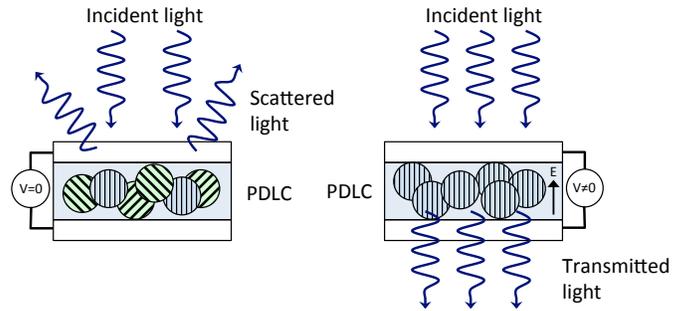
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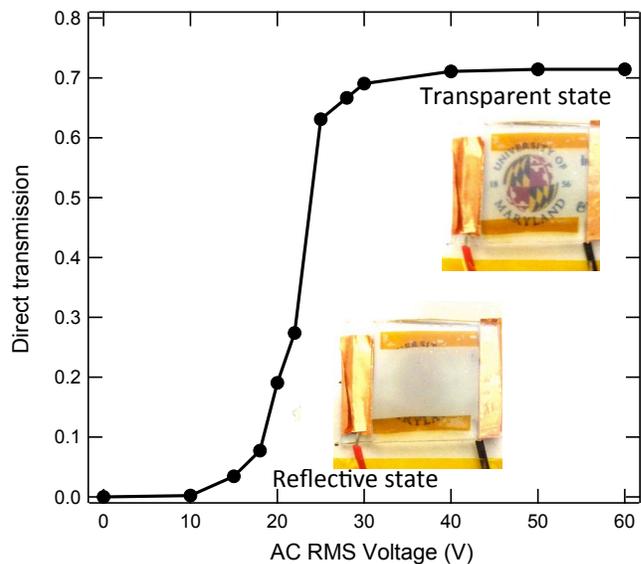
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Schematic of polymer-dispersed liquid crystal (PDLC) device capable of changing between diffusely reflective (left) and transparent (right). Application of an applied electric field causes the liquid crystal to align. The alignment results in an optically isotropic material for the incident light, leading to transmission. The radiation pressure is then controlled via the applied voltage.



Transmission as a function of voltage for device. Insets show the device in operation.

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