
This version is available at https://strathprints.strath.ac.uk/44168/

Strathprints is designed to allow users to access the research output of the University of Strathclyde. Unless otherwise explicitly stated on the manuscript, Copyright © and Moral Rights for the papers on this site are retained by the individual authors and/or other copyright owners. Please check the manuscript for details of any other licences that may have been applied. You may not engage in further distribution of the material for any profitmaking activities or any commercial gain. You may freely distribute both the url (https://strathprints.strath.ac.uk/) and the content of this paper for research or private study, educational, or not-for-profit purposes without prior permission or charge.

Any correspondence concerning this service should be sent to the Strathprints administrator: strathprints@strath.ac.uk
EXPLORING AND EXPLOITING ASTEROIDS WITH LASER ABLATION

Alison Gibbings

Dr Massimiliano Vasile, Dr John-Mark Hopkins, Dr David Burns, Dr Ian Watson

www.strath.ac.uk/space
ASTEROIDS
LASER ABLATION

Laser ablation is achieved by irradiating the surface by a laser light source. The resulting heat sublimes the surface, transforming it directly from a solid to a gas.

Following ablation, large jets of ejecta - gas, dust and large particles - are created. This forms an ejecta cloud & subsequent change of momentum.

Over an extended period of time, provides a continuously low thrust,
MISSION SCENARIO

Induced thrust, $F(t)$

Debris plume

Proximal Motion Orbit

Helocentric NEO orbit
MISSION SCENARIO

The spacecraft(s) consist of:

- A primary mirror, $M_1$
  Focuses the solar rays onto the secondary mirror, $M_2$.
- A set of solar arrays, $S$
  Collects the radiation from the secondary mirror
- A semi conducting laser, $L$
- A steering mirror, $M_d$
  Directs the laser light onto the asteroids
- A large set of radiators $R$,
  Dissipate energy to maintain the solar arrays and laser within the acceptable mission design limits.
MISSION SCENARIO

Ejecta depends on the available energy & efficiency of the ablation process

[Vasile & Maddock, 2010; Phipps 2010; Sanchez, 2009; Kahle 2006]

Plume profile is similar to a rocket exhaust
- Using standard methods of rocket propulsion
- Uniformly expanded gas of ejecta
- No solid particles
- Expanded with a constant scatter factor – 180 degrees

Assumed a spherical, dense, homogenous body
- Forsterite (Mg2Si04) is typically used
- Asteroid has an infinite heat sink
  - Constant internal temperature during ablation

Ejected particles will immediately condense and stick
- Assumptions on the degradation and attenuation

agibbing@eng.gla.ac.uk
The rate of ejecta defines the modulus and direction of the total forces, and therefore the induced motion, exerted onto the asteroid.

Development of the ejecta significantly affects the contamination and operations (i.e. endurance) of any optical surface.

\[ \rho(r, \theta) = \rho \cdot A_p \cdot \frac{d_{\text{SPOT}}^2}{(2r + d_{\text{SPOT}}^2)^2} \left[ \cos \left( \frac{\pi \theta}{2 \theta_{\text{MAX}}} \right) \right]^{\frac{2}{k-1}} \]

[Kahle et al, 2006]
MISSION SCENARIO

The rate of ablation can also be increased with:

- The number of spacecraft
- Combined laser coupling
- Warning/thrusting time

Multiple spacecraft permit the delivery of a much more powerful system.

System redundancy can also be increased.

agibbing@eng.gla.ac.uk
Performing a series of ablation experiments using a 90 W continuous-wave laser

Investigating the development of the ejecta plume, potential for contamination and induced change of momentum during laser ablation.

Calibrate and validate the development of numerical models and existing theory  

[Vasile & Maddock, 2010; Sanchez et al, 2009]
OBSERVED TRENDS

Variation in cone angle, mass flow, and distribution
Ablation process includes solid ejecta particles
Subjected to the volumetric removal of material
Sensitive to the focal point of the laser
Local depositions in and around the ablation volume

$T_0 \sim 0.5 \text{ sec}$

Subjected to the structure and composition of the target material

$T \sim 1 \text{ min } 14 \text{ sec}$

[Gibbings, Vasile et al 2011]

agibbing@eng.gla.ac.uk
MISSION SCENARIO

Laser ablation can be used for a wide range of space-based missions

In-situ Spectra Analysis
Collection & Sample Return
Resource Extraction
Asteroid Deflection
Capture & Control

Durability and diversity of a space-based laser system
Thank you for your attention. Questions please.
References


agibbing@eng.gla.ac.uk