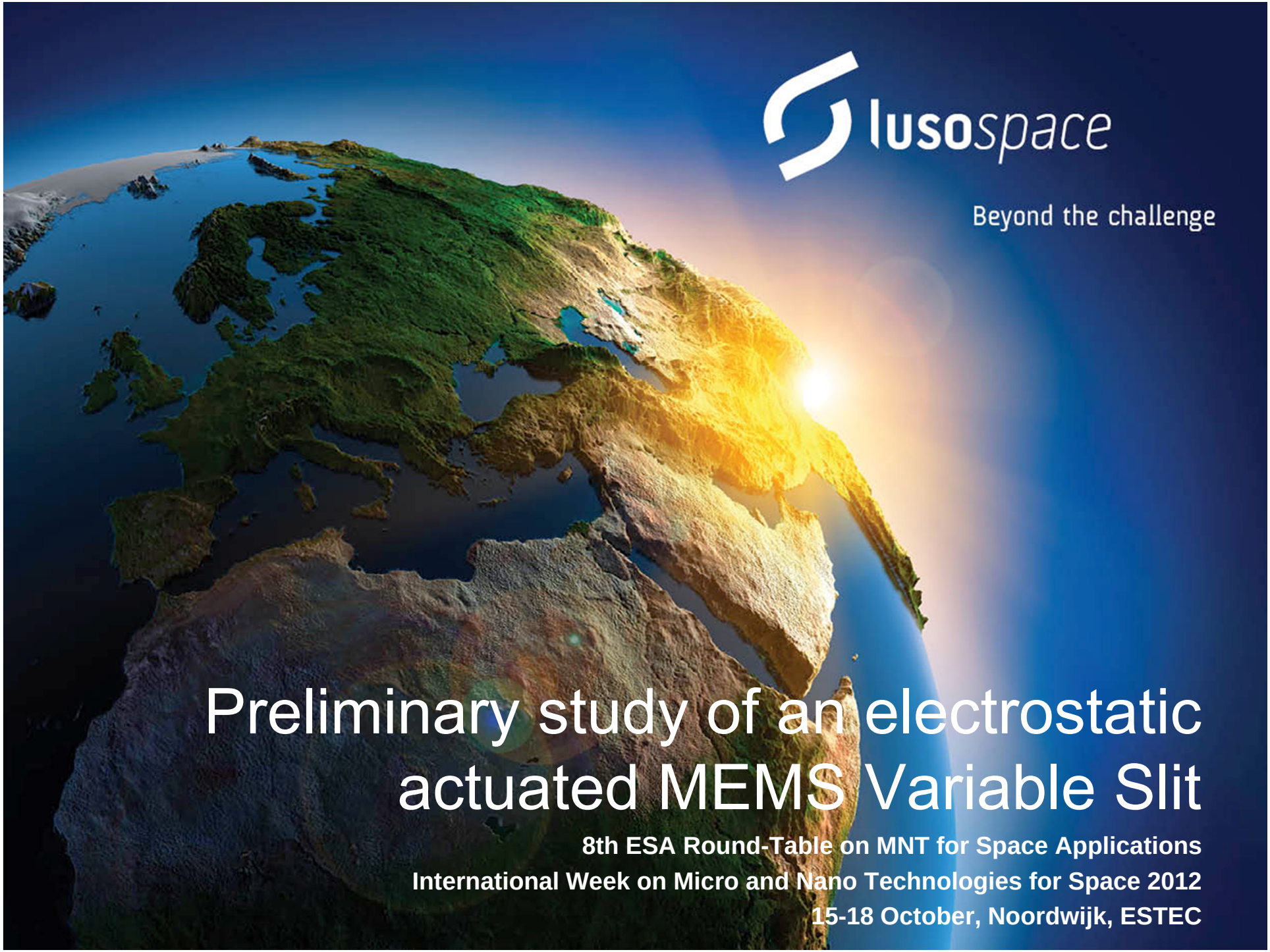


Preliminary study of an electrostatic actuated MEMS Variable Slit

8th ESA Round-Table on MNT for Space Applications
International Week on Micro and Nano Technologies for Space 2012
15-18 October, Noordwijk, ESTEC

"Preliminary study of an electrostatic actuated MEMS Variable Slit"

MEMS Variable Slit - Background

- The proposed concept has been presented and discussed during the project **AO/1-6355/09/NL/LvH -"Optical MEMS for Earth Observation";**
  - Objective: "The objective of this activity shall be the study and assessment of the possible benefits optical MEMS functionalities can/could potentially offer to future Earth Observation at an instrument, system and mission level. "
- The project consortium lead by Lusospace (PT) with Surrey Satellite Technology, (UK) and FCT (PT);
  - M.Abreu (FCT)
  - D.Lobb (SSTL)
  - B.Rodrigues (Lusospace)
- Duration: 12 months, between 2010-2012;

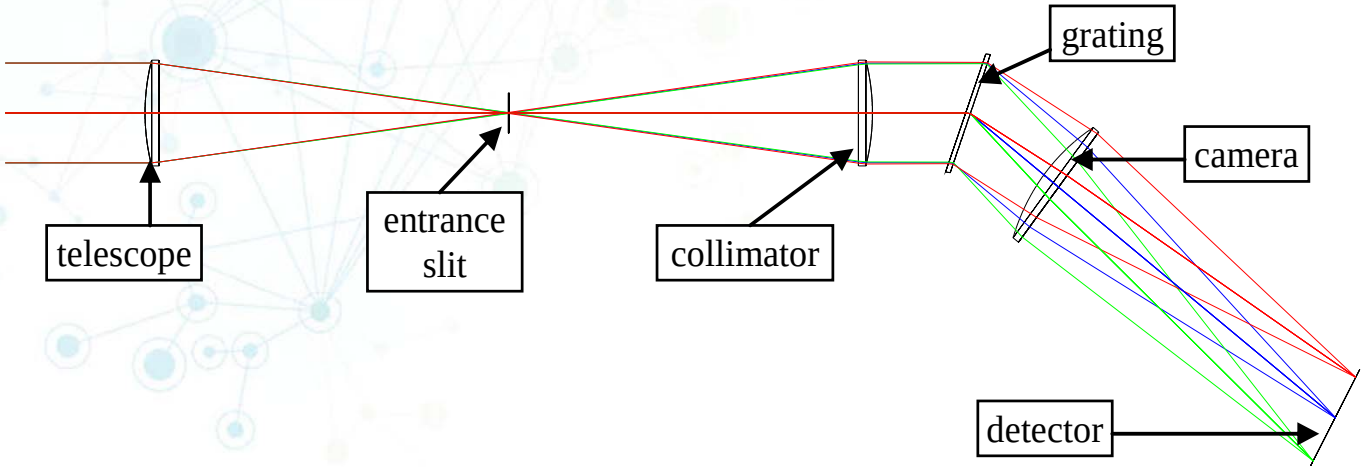
Rua de São Caetano, 16 | 1200-829 Lisboa-Portugal | Tel: +351 21 397 43 63 | +351 21 397 15 40 | info@lusospace.com | www.lusospace.com

"Preliminary study of an electrostatic actuated MEMS Variable Slit"

MEMS variable Slit - Background

- "MEMS devices can in principle be used to define the entrance slits of dispersive imaging spectrometers and be used as part of on-board calibration systems."

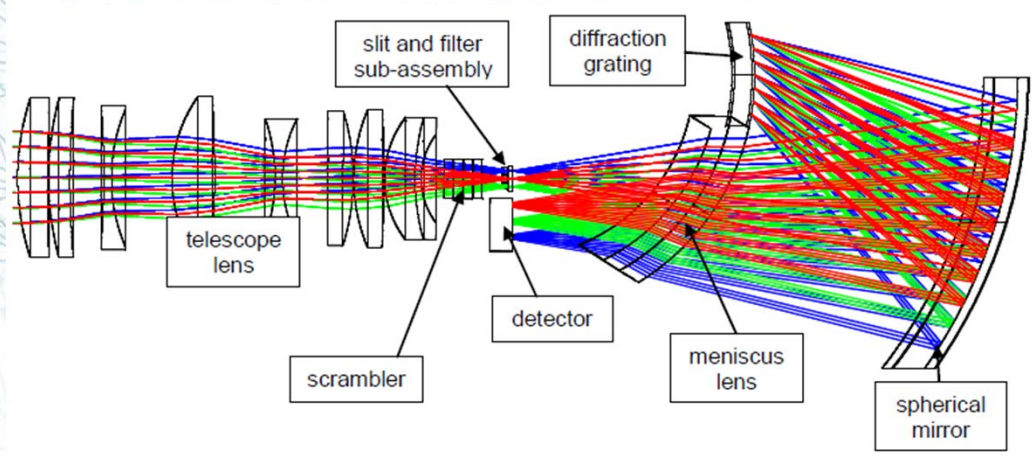
- "The current baseline concept for the narrow-band spectrometer could be altered by use of MEMS-controlled entrance slits."

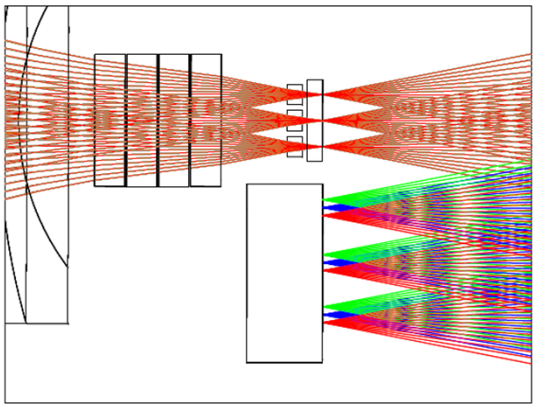


Rua de São Caetano, 16 | 1200-829 Lisboa-Portugal | Tel: +351 21 397 43 63 | +351 21 397 15 40 | info@lusospace.com | www.lusospace.com

"Preliminary study of an electrostatic actuated MEMS Variable Slit"

MEMS variable Slit – FIMAS instrument concept





Current baseline concept relevant features

- 2 slits continuously available;
- Each slit project an image in different areas of the detector plane;
- Low pass band filter per slit to prevent spectrum overlap;

Current baseline concept for FIMAS envisages using a spectrometer with 2 entrance slit widths:

- **0.06mm slit** will provide high SNR for both the O2A and O2B bands at 0.3nm resolution;
- **0.02mm slit** will give 0.1nm resolution only for the O2A band;

Rua de São Caetano, 16 | 1200-829 Lisboa-Portugal | Tel: +351 21 397 43 63 | +351 21 397 15 40 | info@lusospace.com | www.lusospace.com

"Preliminary study of an electrostatic actuated MEMS Variable Slit"

MEMS variable Slit – FIMAS instrument context

Functionality	Concept	Advantages	Issues
Slit function	Adjust the width of a **single slit** between two values	- Continuous slit width variation allows in-flight experiments with a range of options; - It will not be necessary to restrict spectral bands to avoid overlaps between spectra from separate slits;	- Long term operation stability; - Operational uniformity; - Operational repeatability; - Time sharing losses (fine to coarse resolution);
	Select between **two slits** of different widths	-It separates the problem of defining a good slit from the problem of making the switch between slit widths;	- Slit selection mechanism; - Time sharing losses (fine to coarse resolution);

Rua de São Caetano, 16 | 1200-829 Lisboa-Portugal | Tel: +351 21 397 43 63 | +351 21 397 15 40 | info@lusospace.com | www.lusospace.com

"Preliminary study of an electrostatic actuated MEMS Variable Slit"

lusospace

MEMS variable Slit - Targeted specifications in a FIMAS-like application

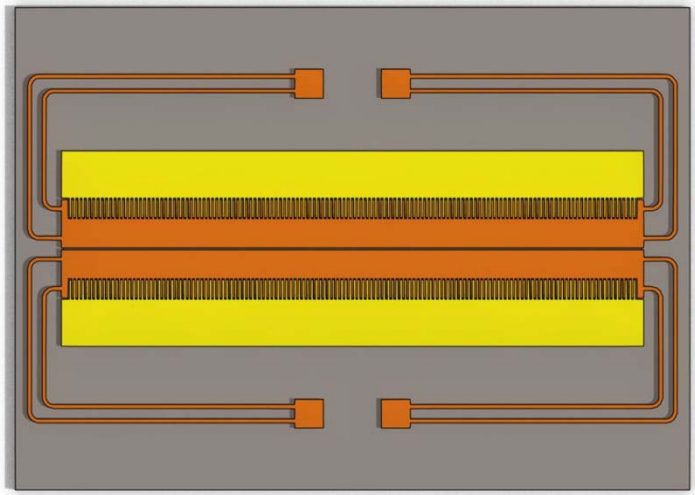
Parameter	Value	Notes
Type of MEMS	Shutter	-
Effective slit length	30mm	-
Slit width range	0.1mm to 0.01mm	Spectral resolution intervals from 0.5nm (O2A and O2B) to 0.05nm (Ha and Hb)
Width uniformity	0.5 microns	Critical in the determination of the slit image intensity distribution in each wavelength.
Width repeatability	0.5 microns	Critical in the determination of the slit image intensity distribution in each wavelength
Duty cycle	One change per second	Sampling 7km ground-tracks
Switching period	<0.1s	-
Life	>3 years	-

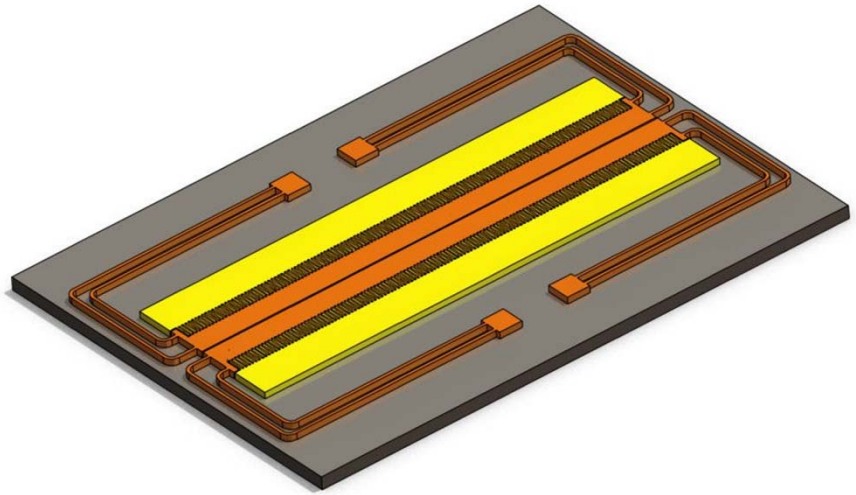
Rua de São Caetano, 16 | 1200-829 Lisboa-Portugal | Tel: +351 21 397 43 63 | +351 21 397 15 40 | info@lusospace.com | www.lusospace.com

"Preliminary study of an electrostatic actuated MEMS Variable Slit"

MEMS variable Slit – Concept*

- ❑ MEMS device is based on an electrostatic activation principle.
- ❑ The proposed Si-MEMS device is composed of 2 movable comb drives to reach maximum stroke.
- ❑ The maximum slit width is achieved when both slits are actuated – ON position. The minimum slit width is reached in the rest position – OFF position.
- ❑ Manufacturing process: surface micromachining, RIE,...





*drawings not to scale

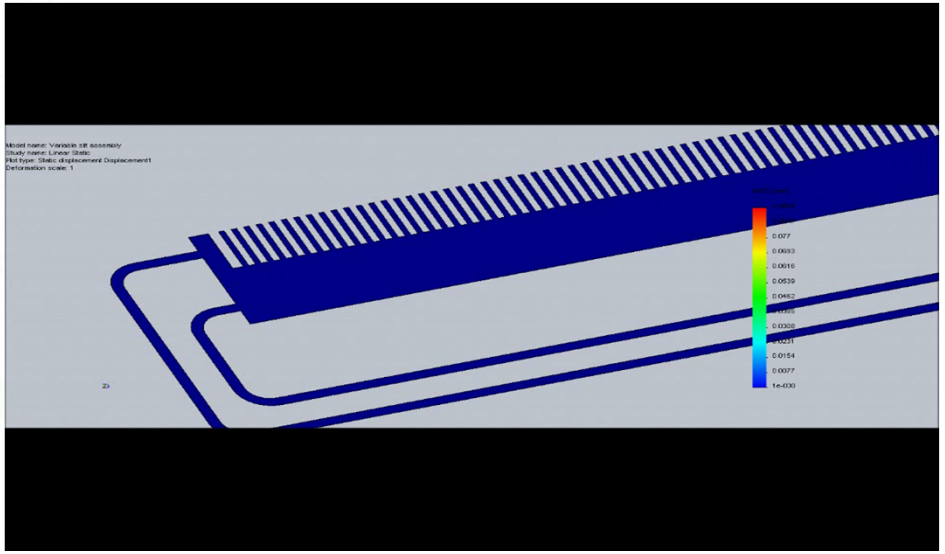
Rua de São Caetano, 16 | 1200-829 Lisboa-Portugal | Tel: +351 21 397 43 63 | +351 21 397 15 40 | info@lusospace.com | www.lusospace.com

"Preliminary study of an electrostatic actuated MEMS Variable Slit"

lusospace

MEMS Variable Slit – Operation description

Features	❑ A varying slit width is achieved by 2 parallel movable edges. ❑Comb drives are connected length wise to the movable edge for position control . ❑ The movable edge is connected to the device structure by a spring structure connected to the extremities.



Operation	A rise in the driving voltage exerts an attractive force between the opposite finger banks of the comb drive.	**ON state**	Both comb drives are activated, maximum slit width
		OFF state	Both comb drives are neutral -> minimal slit width

*drawings not to scale

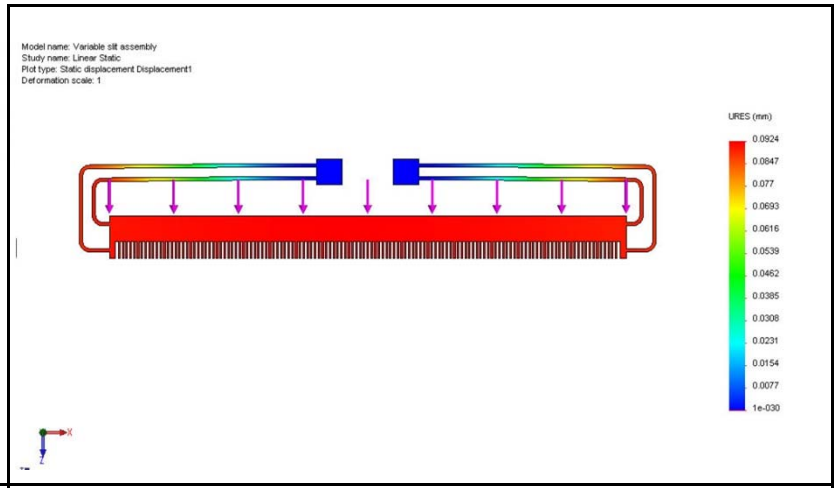
Rua de São Caetano, 16 | 1200-829 Lisboa-Portugal | Tel: +351 21 397 43 63 | +351 21 397 15 40 | info@lusospace.com | www.lusospace.com

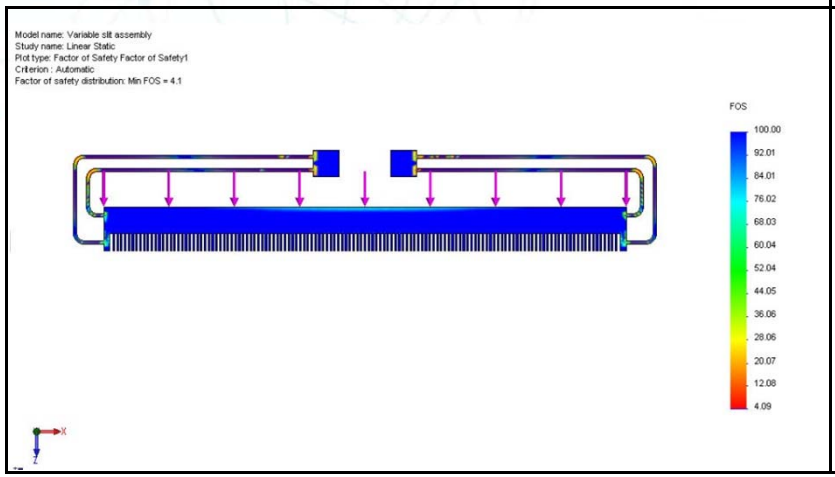
"Preliminary study of an electrostatic actuated MEMS Variable Slit"

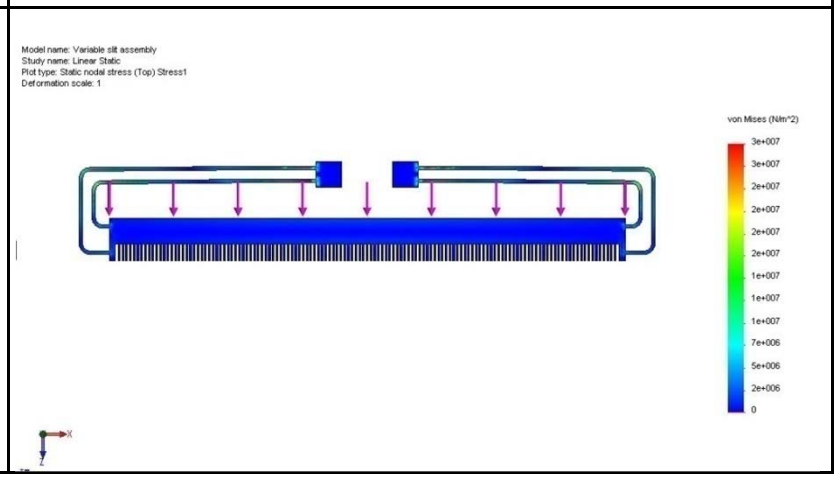
MEMS Variable Slit – Preliminary mechanical analysis

Bending Structure Mechanical Analysis

-Static displacement: 900µm, 0.0527N applied force;
-Factor of safety distribution: 4.1
-Static nodal stress







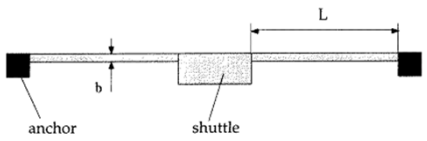
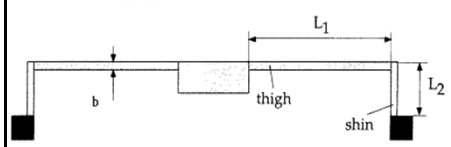
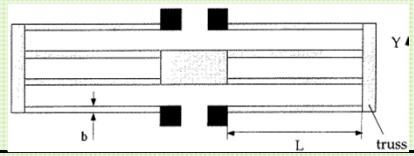
"Preliminary study of an electrostatic actuated MEMS Variable Slit"

MEMS Variable Slit – Spring mechanism

Crititcal Parameters:

- Flexing structure architecture
- Displacement
- Movement stability - flexiblibility in one direction but stiffness in the orthogonal directions
- Edge uniformity over 30mm length

(3)

	Fixed–fixed beam	Crab-leg flexure	Folded-flexure design
Concept			
Stiffness ratio	High (1.25x10^5)	Medium	Medium
Issues	Non-linear force-to-displacement relation	Large reduction of the stiffness ratio over the FxFxB.	Stiffness in the x-direction decreases with increasing displacement in the y-direction.

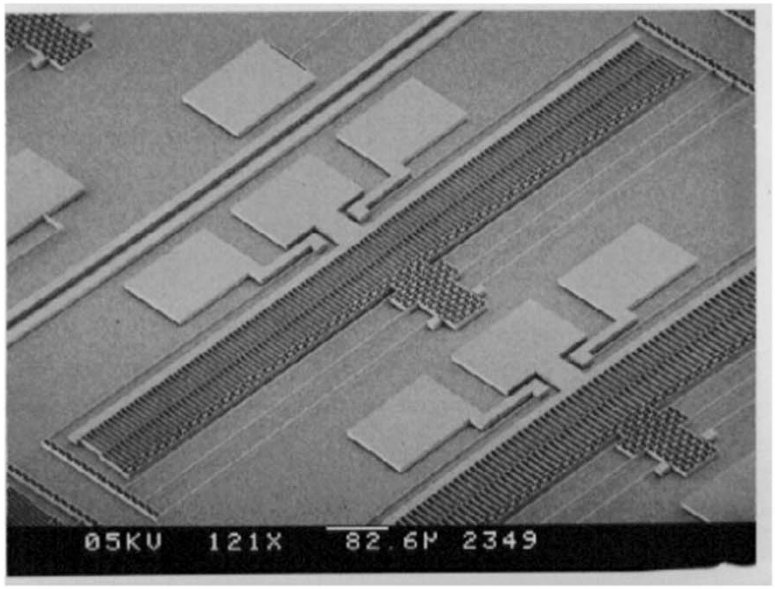
Rua de São Caetano, 16 | 1200-829 Lisboa-Portugal | Tel: +351 21 397 43 63 | +351 21 397 15 40 | info@lusospace.com | www.lusospace.com

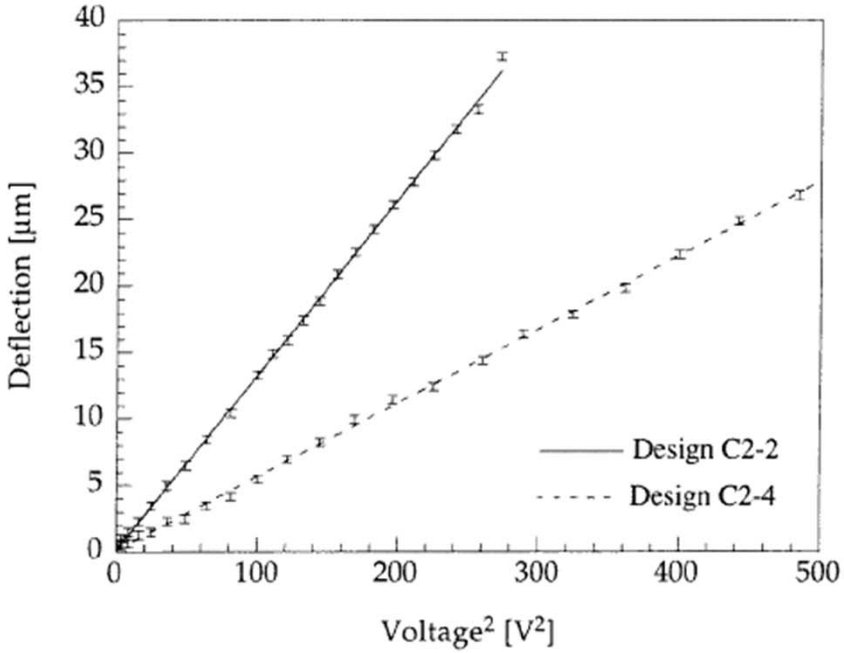
"Preliminary study of an electrostatic actuated MEMS Variable Slit"

MEMS Variable Slit – The comb drive actuator

40um displacement concept description

- Si wafer->SiO2 ->Poly-Si(LPCVD) ->Br-doping-> SiO2(PECVD)->RIE(CH4)
- Folded flexure mechanism
- Stroke up to 40um for a 20-26V actuation





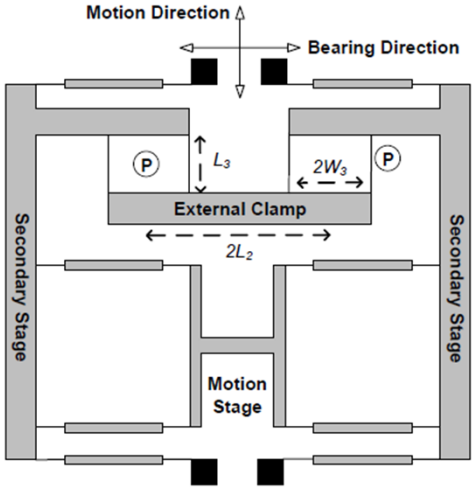
(3) *Rob Legtenberg, A W Groeneveld and M Elwenspoek , MESA Research Institute*

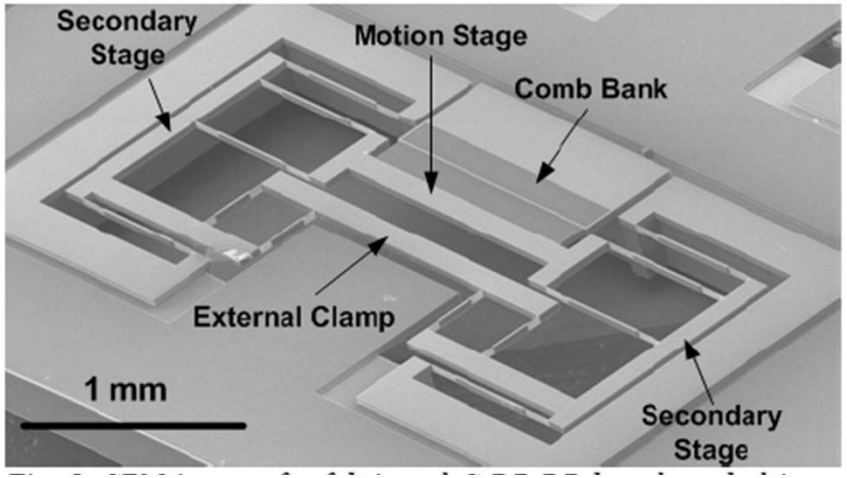
"Preliminary study of an electrostatic actuated MEMS Variable Slit"

MEMS Variable Slit – The comb drive actuator

250um displacement concept description

- SOI wafer-> Patterning ->DRIE
- Clamped Paired Double Parallelogram (C-DP-DP) flexure mechanism
- Stroke up to 250um for a 120V actuation
- Displacement measurements repeatable within 1 µm.



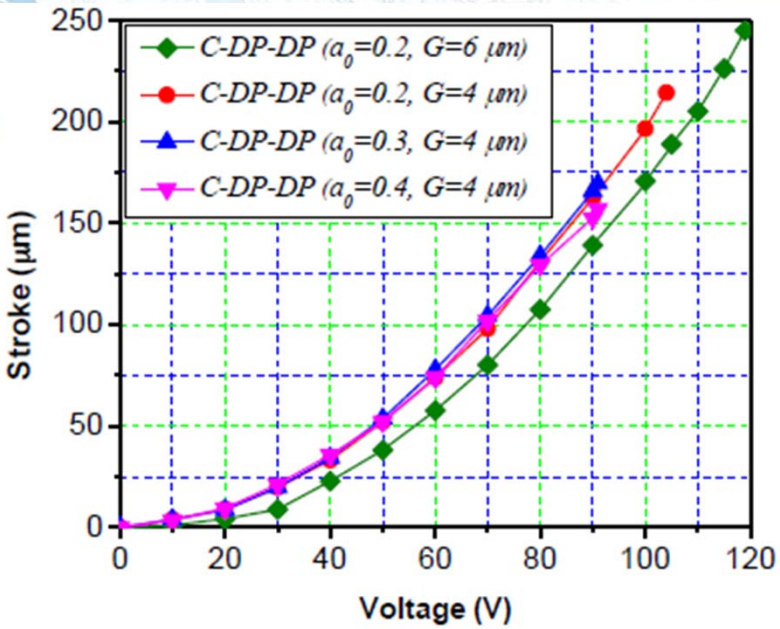


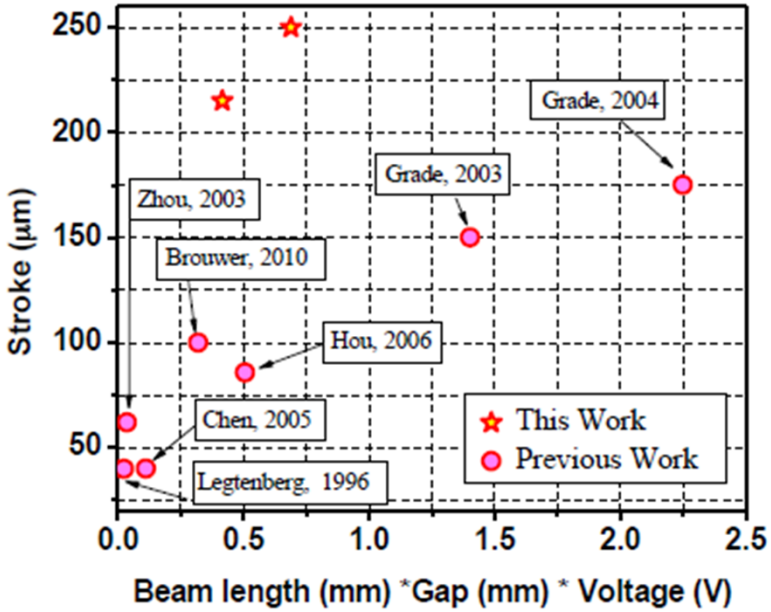
(5) Olfatnia, M.; Sood, S.; Gorman, J. J., Awtar, University of Michigan, USA

Rua de São Caetano, 16 | 1200-829 Lisboa-Portugal | Tel: +351 21 397 43 63 | +351 21 397 15 40 | info@lusospace.com | www.lusospace.com

"Preliminary study of an electrostatic actuated MEMS Variable Slit"

MEMS Variable Slit – The comb drive actuator





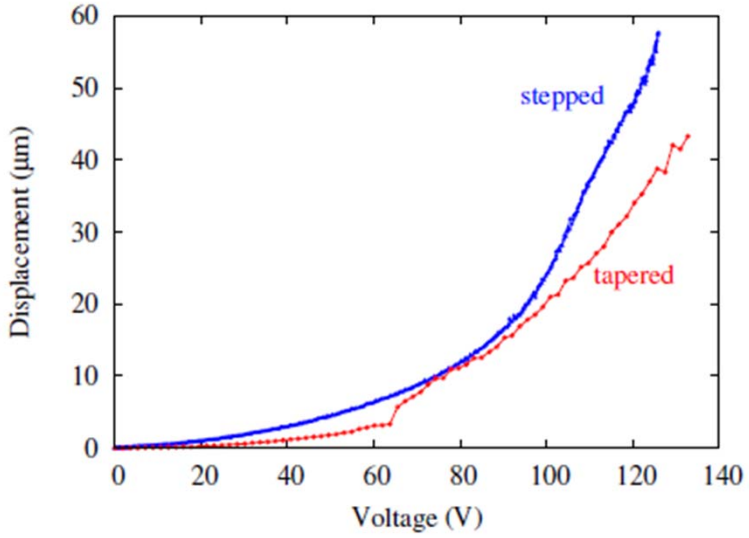
(5) Olfatnia, M.; Sood, S.; Gorman, J. J., Awtar, University of Michigan, USA

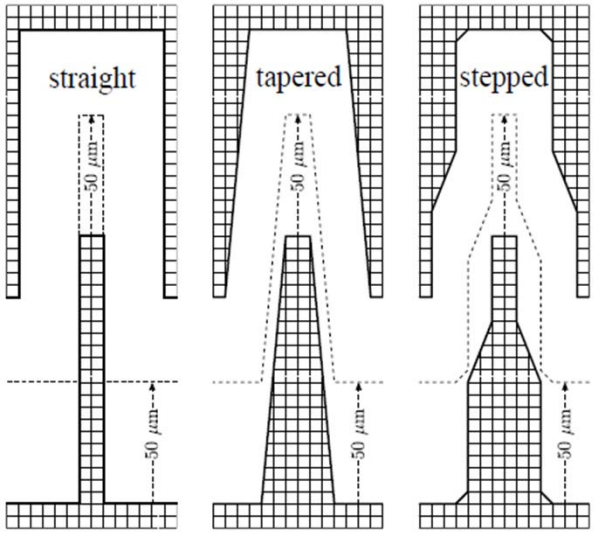
Rua de São Caetano, 16 | 1200-829 Lisboa-Portugal | Tel: +351 21 397 43 63 | +351 21 397 15 40 | info@lusospace.com | www.lusospace.com

"Preliminary study of an electrostatic actuated MEMS Variable Slit"

MEMS Variable Slit – The comb drive actuator

- 3 finger shapes compared;
- Stepped finger shape achieves the highest stroke;





(6) J.B.C. Engelen1, M.A. Lantz2, H.E. Rothuizen2, L. Abelmann1, and M.C. Elwenspoek1;3 1 MESA+ and IMPACT Research Institutes, University of Twente, Enschede, The Netherlands,

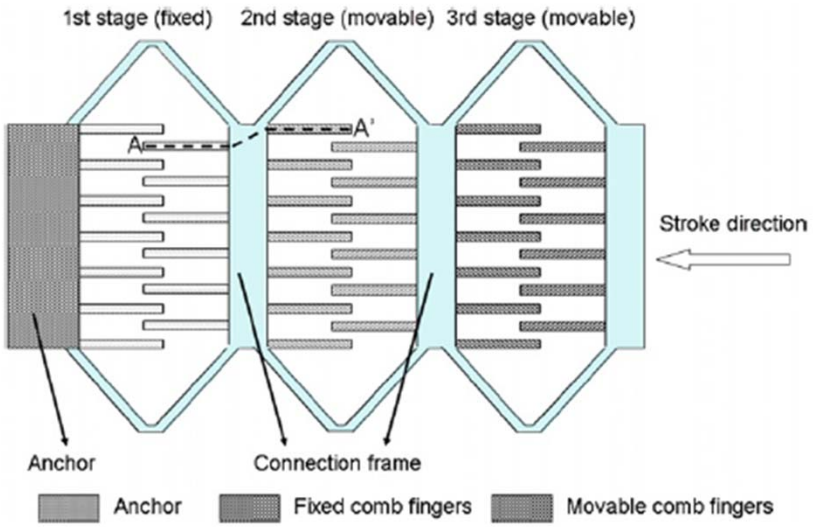
Rua de São Caetano, 16 | 1200-829 Lisboa-Portugal | Tel: +351 21 397 43 63 | +351 21 397 15 40 | info@lusospace.com | www.lusospace.com

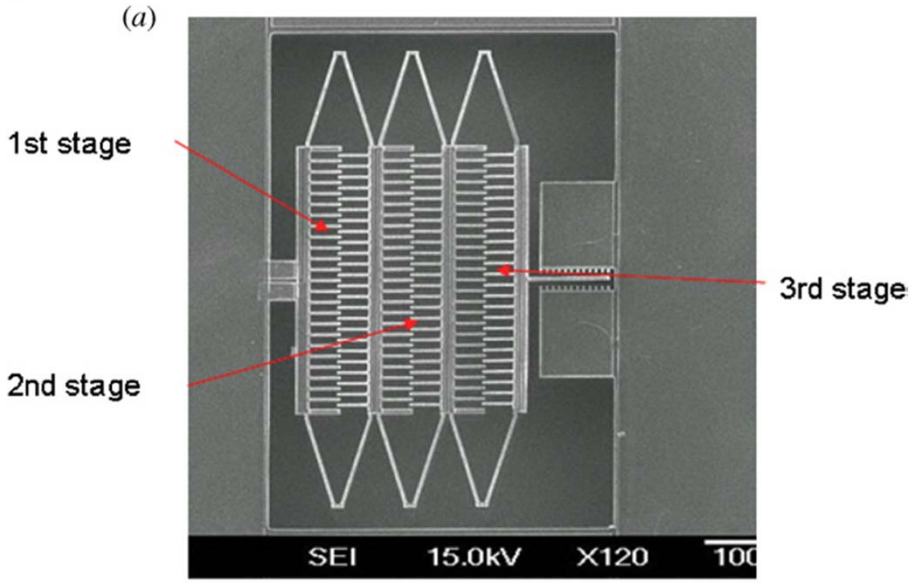
"Preliminary study of an electrostatic actuated MEMS Variable Slit"

MEMS Variable Slit – The comb drive actuator

Concept description

- Concept based on multiple comb drives
- Cascade actuator extends the stroke nearly to 200% as compared with the actuator with a single stage.





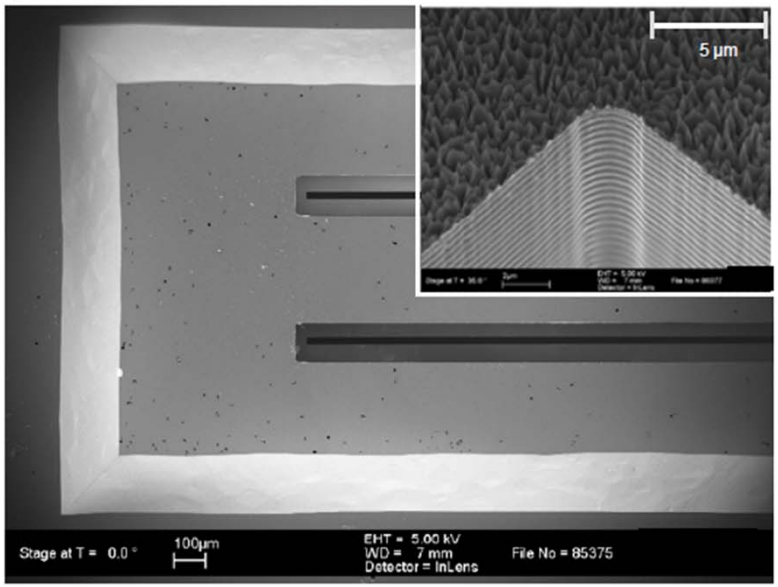
(7) Jin-Chern Chiou, Yung-Jiun Lin and Chin-Fu Kuo,

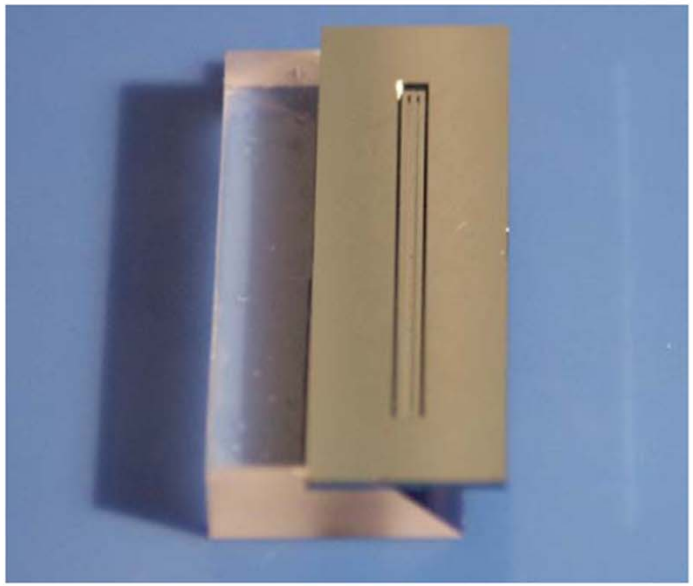
Rua de São Caetano, 16 | 1200-829 Lisboa-Portugal | Tel: +351 21 397 43 63 | +351 21 397 15 40 | info@lusospace.com | www.lusospace.com

"Preliminary study of an electrostatic actuated MEMS Variable Slit"

MEMS Variable Slit operational issues – Manufacturing

- MEMS dual-slit (4)
  - ❑ Si structure coated with an absorbing layer
  - ❑ (2x) 24um slit width
  - ❑ 480um slit separation
  - ❑ 24mm slit length





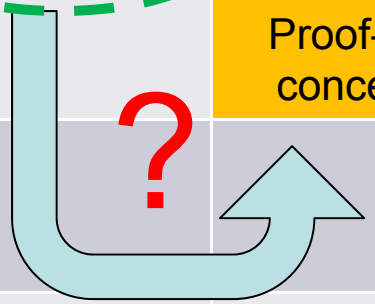
(4) B. Sang, J. Schubert, S. Kaiser, V. Mogulsky, C. Neumann, K.-P. Förster, S. Hofer, T. Stufflera,H. Kaufmannb, A. Müllerc, T. Eversberg, C. Chlebekd

Rua de São Caetano, 16 | 1200-829 Lisboa-Portugal | Tel: +351 21 397 43 63 | +351 21 397 15 40 | info@lusospace.com | www.lusospace.com

"Preliminary study of an electrostatic actuated MEMS Variable Slit"

MEMS Variable Slit – Development Roadmap

Development Stage	T0	T0+1y	T0+3y	T0+4y	T0+6y
TRL1	Concept presentation				
TRL2		Proof-of-concept			
TRL3			Laboratorial MEMS validation		
TRL4				MEMS Eval&Rel assessment	
TRL5-8					(...)



Rua de São Caetano, 16 | 1200-829 Lisboa-Portugal | Tel: +351 21 397 43 63 | +351 21 397 15 40 | info@lusospace.com | www.lusospace.com

"Preliminary study of an electrostatic actuated MEMS Variable Slit"

MEMS Variable Slit – Conclusions

- A MEMS variable slit concept for in-flight spectrometer calibration has been presented. The proposed concept requires simulation, analysis and validation before a functional model is available;
- The proposed design relies on simple concepts, known materials and actuation mechanisms principles;
- 30mm slit length and 900µm maximum displacement far exceeds the typical comb drive operation range. Functionality must be validated.;
- Manufacturer's feedback about concept feasibility is critical.
- Operational requirements must be defined in order to validate dimensional design;
- Application usefulness must be confirmed;

Rua de São Caetano, 16 | 1200-829 Lisboa-Portugal | Tel: +351 21 397 43 63 | +351 21 397 15 40 | info@lusospace.com | www.lusospace.com

“Preliminary study of an electrostatic actuated MEMS Variable Slit”

lusospace

Q&A

Rua de São Caetano, 16 | 1200-829 Lisboa-Portugal | Tel: +351 21 397 43 63 | +351 21 397 15 40 | info@lusospace.com | www.lusospace.com

"Preliminary study of an electrostatic actuated MEMS Variable Slit"

References

(1) Optical MEMS for Earth Observation Project – "**Baseline concepts of optical MEMS enhanced Earth Observation instruments**" - Technical Note 2

(2) Optical MEMS for Earth Observation Project - "**Baseline design of selected Earth Observation instruments based on optical MEMS - MEMS Analysis section**" - Technical Note 7

(3) "**Comb-drive actuators for large displacements**",Rob Legtenberg, A W Groeneveld and M Elwenspoek MESA Research Institute, University of Twente, PO Box 217, 7500 AE Enschede, The Netherlands, Received 30 November 1995, accepted for publication 4 June 1996

(4) **The EnMAP hyperspectral imaging spectrometer: instrument concept, calibration and technologies** B. Sang, J. Schubert, S. Kaiser, V. Mogulsky, C. Neumann, K.-P. Förster, S. Hofer, T. Stufflera,H. Kaufmannb, A. Müllerc, T. Eversberg, C. Chlebekd, aKayser-Threde GmbH, Wolfratshauser Str. 48, 81379 Munich, Germany, bHelmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum - GFZ ,Telegrafenberg A17, 14473 Potsdam, Germany, cGerman Remote Sensing Center, Münchner Str. 20,82234 Wessling, Germany, dGerman Aerospace Center Space Agency, Königswinterer Str. 522-524, 53227 Bonn, Germany

(5) **Large Stroke Electrostatic Comb Drive Actuators Based on a Novel Flexure Mechanism**, Olfatnia, M.; Sood, S.; Gorman, J. J**.,** Awtar, S.; Proceedings of the Hilton Head 2012: Solid-state Sensors, Actuators and Microsystems Workshop , June 20, 2012

(6) **SHAIMPROVED PERFORMANCE OF LARGE STROKE COMB-DRIVE ACTUATORS BY USING A STEPPED FINGER SHAPE**, J.B.C. Engelen1, M.A. Lantz2, H.E. Rothuizen2, L. Abelmann1, and M.C. Elwenspoek1;3 1 MESA+ and IMPACT Research Institutes, University of Twente, Enschede, The Netherlands, 2 IBM Research, Zurich Research Laboratory, Ruschlikon, Switzerland, 3 Freiburg Institute for Advanced Studies (FRIAS), Albert-Ludwigs-Universit¨at, Freiburg, Germany

(7) **Extending the traveling range with a cascade electrostatic comb-drive actuator,** Jin-Chern Chiou, Yung-Jiun Lin and Chin-Fu Kuo, Department of Electrical and Control Engineering, National Chiao Tung University, Hsin-Chu, Taiwan,Republic of China

Rua de São Caetano, 16 | 1200-829 Lisboa-Portugal | Tel: +351 21 397 43 63 | +351 21 397 15 40 | info@lusospace.com | www.lusospace.com