

Qualification of optical and optoelectrical modules with MEMS subcomponents

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testlab for opto +
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tec** GmbH
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Ihr Partner für Opto- und Mikroelektronik

1. unabhängig und neutral
2. Modernes Analyse- und Testequipment
3. Testdienstleistungen aus einer Hand
 - ◆ Test von elektronischen und optoelektronischen Bauelementen
 - ◆ Qualifikation nach
 - Telcordia, MIL, JEDEC, ESA, DIN, IEC
 - AEC-Q 100/200
 - ◆ Fehleranalyse
 - ◆ Beratung
 - ◆ Logistik / Supply Chain Service

...vom Chip bis zur Baugruppe

- ◆ Introduction
 - MEMS based optical devices
 - Qualification test program
 - Optimisation of Qualification process
 - Failure Modes
 - Conclusions

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Introduction

MEMS based optical devices

Qualification test program

Optimisation of qualification process

Failure modes

Conclusions



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Introduction

- ◆ MEMS components present core elements of optoelectronic devices (switch, attenuators, ROADMs)
- ◆ Technology is not considered mature
- ◆ severe requirements for reliability
- ◆ established standards for various markets
- ◆ Qualification is a costly and time consuming process



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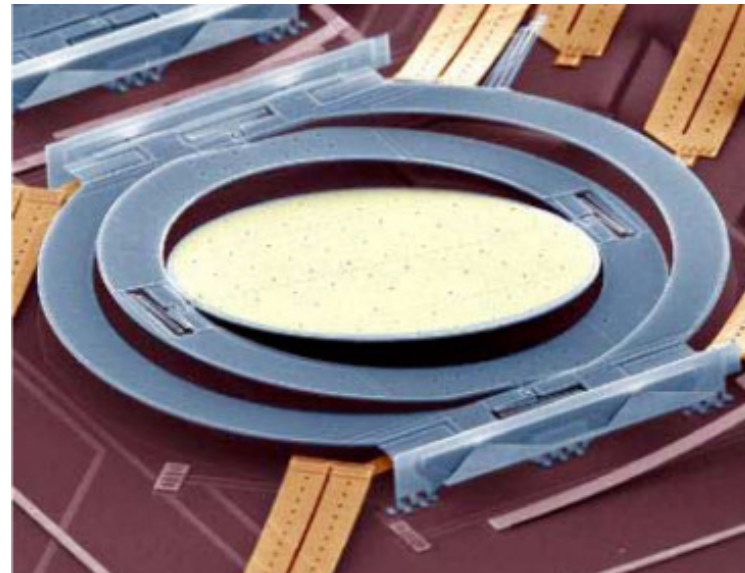
MEMS based optical devices

Operational Principles: mechanical movement of parts

- ◆ tilt of MEMS mirror (deflection of optical beam)
- ◆ moving vane (absorption / reflection of optical beam)
- ◆ Bending of MEMS mirror (change of cavity resonance)

Actuation mechanism:

- ◆ electro static
- ◆ thermal
- ◆ magnetic
- ◆ piezo electric



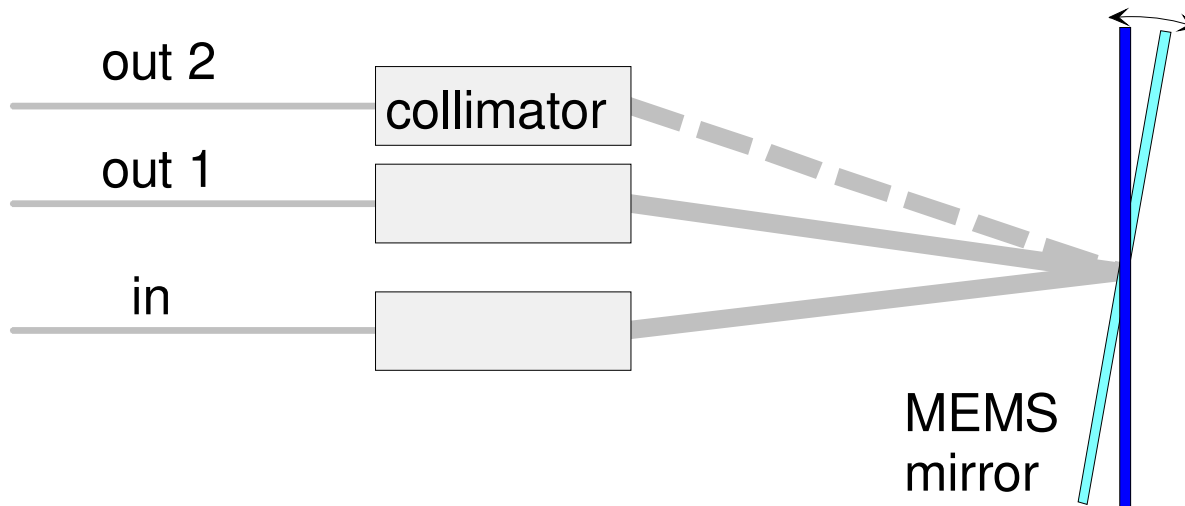
Lucent



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MEMS based optical devices

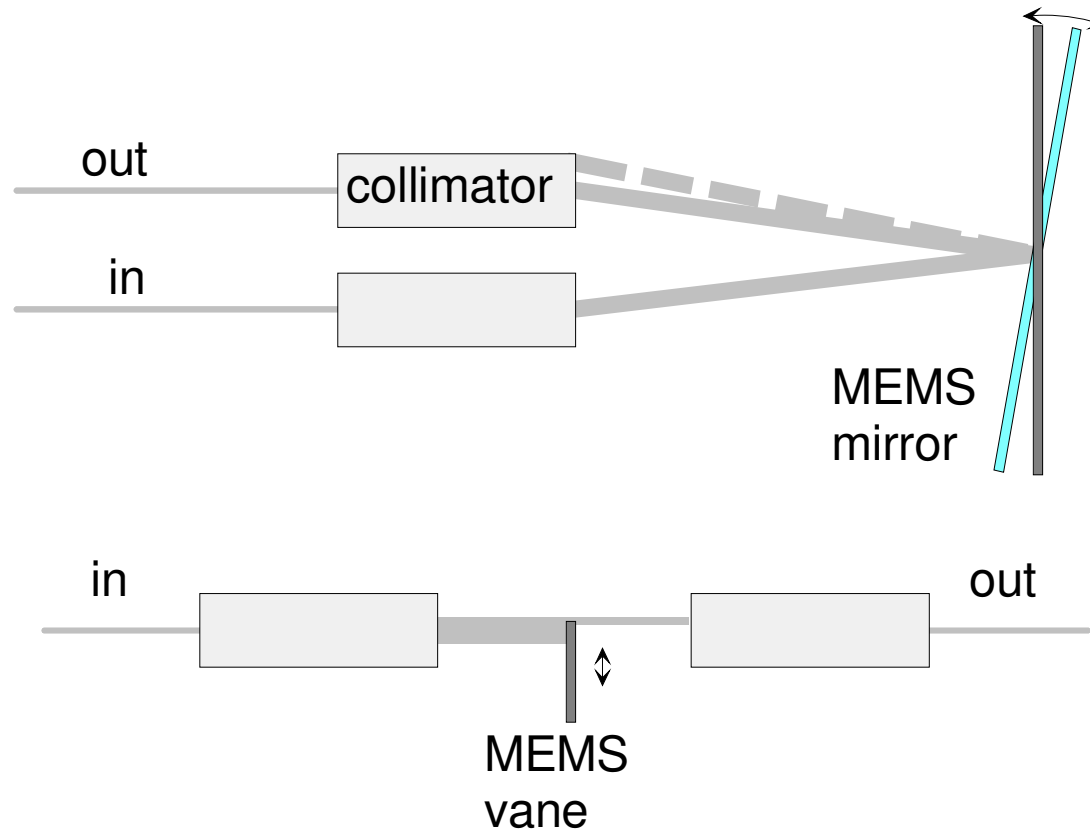
Optical Switch (1x2, nxn: optical cross connects OXC)



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MEMS based optical devices

Variable optical attenuator

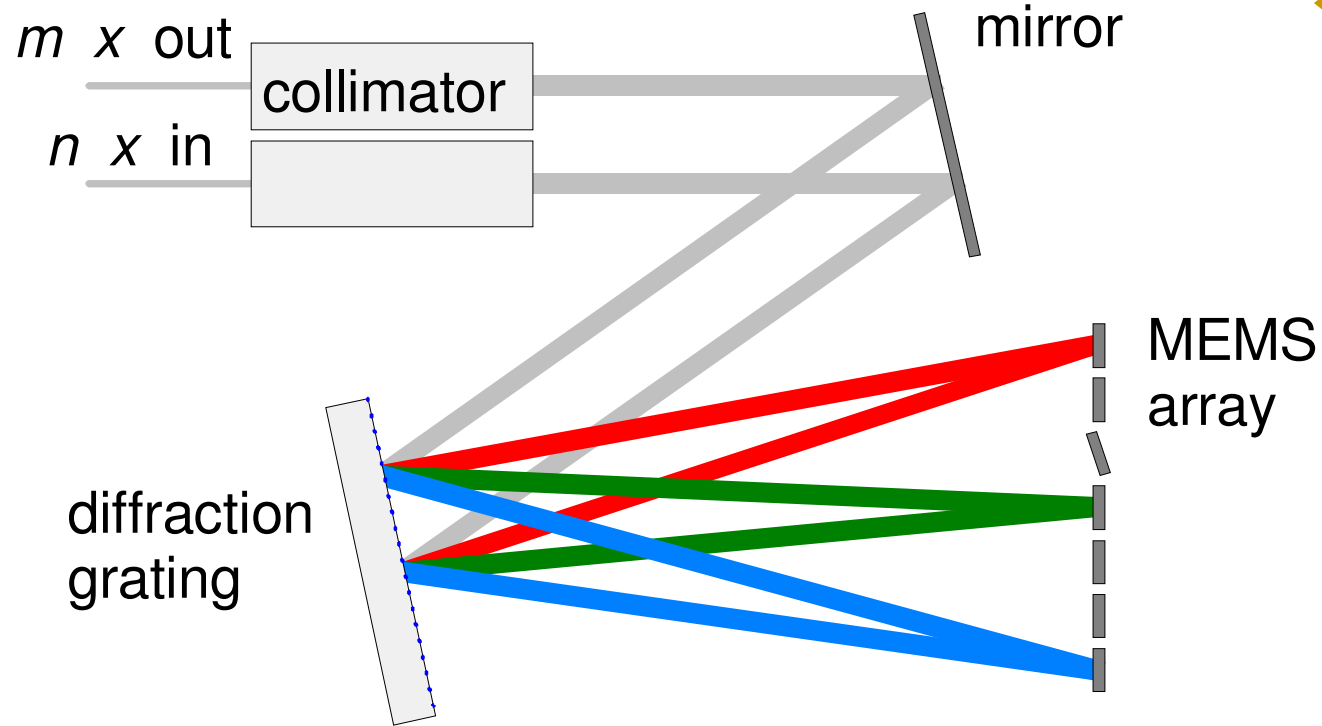


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MEMS based optical devices

Reconfigurable Optical Add Drop Multiplexer ROADM

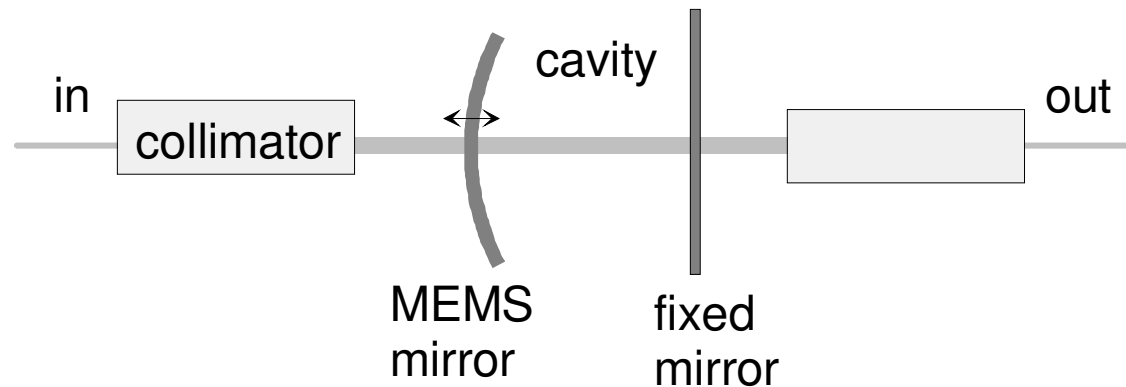
- λ -Blocker
- wavelength-selective switch
- dynamic gain / channel equalizers



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MEMS based optical devices

Tunable Filters (Fabry-Perot cavity with fixed mirror and MEMS mirror)



Channel Monitors (spectral analysis of signal)

Tunable Lasers (external cavity with MEMS mirror)



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Qualification Plan

specific standards for MEMS devices do not exist

starting point: reliability risk assessment

Qualification plan determined by

- ◆ Application (environmental conditions)
- ◆ Market requirements
- ◆ Integration Level (Complexity): Component - Module

program is based on various applicable standards



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Relevant Qualification Standards



Telcordia for Telecom	GR-1221-CORE	Generic Reliability Assurance Requirements for Passive Optical Components
	TR-NWT-001073	Generic Requirements for Fiber Optic Switches
	GR-468-CORE	Generic Reliability Assurance Requirements for Optoelectronic Devices
	GR-1312-CORE	Generic Requirements for Optical Fiber Amplifiers and Proprietary Dense Wavelength-Division Multiplexed Systems
AEC-Q for Automotive	AEC-Q 100 - REV - F	Stress Test Qualification For Integrated Circuits
	AEC-Q 101 - REV - C	Stress Test Qualification for Automotive Grade Discrete Semiconductors
ESA-SCC for Aero-Space	ESCC 9020	Generic Specification for Charge Coupled Devices, Silicon, Photosensitive

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Reference to IEC, MIL-STD 883, JEDEC, ESA-SCC, DIN, EIA TIA

Typical qualification tests

Mechanical Tests

- ◆ Vibration
- ◆ Shock
- ◆ Fiber

Tests are meant to verify robustness during transport, storage, installation, and operation



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Typical qualification tests

Environmental tests

- ◆ Temperature cycling
- ◆ Temperature storage
- ◆ High temperature / humidity storage (static, cyclic)

Tests are meant to verify

- ◆ general robustness
- ◆ sensitivity to high temperature and humidity (long term reliability – aging mechanisms)



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Typical qualification tests

Other Tests

- ◆ Endurance (in operation; durability)
- ◆ Vibration / Shock in operation (mechanical sensitivity)
- ◆ ESD (electro-static discharge)
- ◆ thermal shock (hermetic packages)
- ◆ RGA (residual gas analysis for hermetic packages)



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Qualification test program for MEMS optical attenuator (Telecom)



Test	Conditions	Sample Size/ Failure allowed
Mechanical Shock	500g, 1.0 msec, 5x per dir., 6 directions	11/0
Vibration	20-2000 Hz @ 20 G, 4min/cycle, 4cycles/axis	11/0
Temperature Cycling	-40 °C to 85 °C, 100 cycles, 500 cycles for info	11/0
High Temperature Storage	85 °C, 2000h, 5000h for info	11/0
Damp Heat	85 °C/85 %RH, 500h, 2000h for info	11/0
Temperature-Humidity Cycling	-40 °C to +75 °C, 10% - 80% RH, 42 cycles, 14 days	11/0
Thermal Shock	$\Delta T = 100 \text{ }^\circ\text{C}$, transition < 2min	11/0
Low Temp Storage	-40 °C, 2000h	11/0
Attenuation Cycling	tbd	11/0
ESD	> 2000V HBMV	6/0
Fiber integrity	Cable Retention, Side Pull, Twist	11/0

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Optimisation of Qualification Process

Qualification is quite expensive and time consuming

- ◆ number of individual test (incl. long duration)
- ◆ large number of DUTs
- ◆ qualification of subcomponents

save expenses:

- ◆ sequential tests (use same DUTs for different tests)
- ◆ similarity approach if applicable
- ◆ avoid failures in final qualification by effective measures in advance (design for reliability, FMEA, pretest program)



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Optimisation of Qualification Process

Failure Mode and Effect Analysis (FMEA)

- ◆ analyse all kinds of failure modes with best technical knowledge
- ◆ assess severity of effects on performance & environment
- ◆ estimate probability of occurrence

→ identify most significant risks

→ determine corrective actions



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Optimisation of Qualification Process

Pretest Program

- ◆ limit potential risks for final qualification
- ◆ detect unknown failure modes & weak parts
- ◆ test to failure (determine stress limits)
- ◆ selection of DUTs: various integration levels
- ◆ specific test conditions



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Failure Modes of MEMS devices

good knowledge of failure modes is important for designing a reliable product

design and technology are evolving: new failure modes

package & assembly have major impact on functionality and on reliability

failure modes to be considered:

- ◆ MEMS-Subcomponent
- ◆ Module level
- ◆ (electronics or SW are not included here)



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Failure Modes of MEMS devices



Failure Mode	Effect	Root Cause	Test
Stiction	MEMS movement blocked catastrophic failure	high voltage high mechanical stress humidity condensation	test to failure (shock, ESD)
ESD damage	catastrophic failure	stiction due to high voltage	ESD
Fatigue	degradation of performance	stress relaxation creep of coating	high temperature storage
Breakage	catastrophic failure	high mechanical stress	shock
Drift @ operational mechanical stress	performance failures	sensitivity to operational mechanical stress	operational shock & vibration
Bending / Distortion	temperature dependance of performance	thermal mismatch	functional test
Contaminants / dust	degradation of performance	lack of hermeticity particles inside package	hermeticity clean room
Change of internal atmosphere & pressure	degradation of performance	lack of hermeticity	thermal shock & hermeticity
Dielectric charging	parameter drift, hysteresis	drift of electrical charges	functional test
Corrosion	degradation of performance	electro-chemical reaction	op. damp heat

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Conclusions

MEMS products have shown potential for high reliability

Design and technology of MEMS not considered mature
(rapidly evolving)

Comprehensive analysis and test programs in advance to
final qualification needed to get good understanding of
reliability

Qualification program according to applicable standards is
must to enter the market

Expenses to be saved by good organisation of qualification
program incl. prequal tests



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Thank you for your attention

*microtec,
For more than 20 years
The test house for*

- *Tests*
- *Qualification*
- *Failure Analysis*



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...focussed on quality.



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