ADVANCED THIN FILMS

Review of Ion Beam Sputtering

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.History of the Kaufman ion source

.Early days of ion beam sputtering

.The modern IBS machines

.Characteristics of IBS optical coatings

-environmental stability

-losses

-stress

.Materials which can be deposited using IBS

.”Intrinsic” contaminants in IBS films

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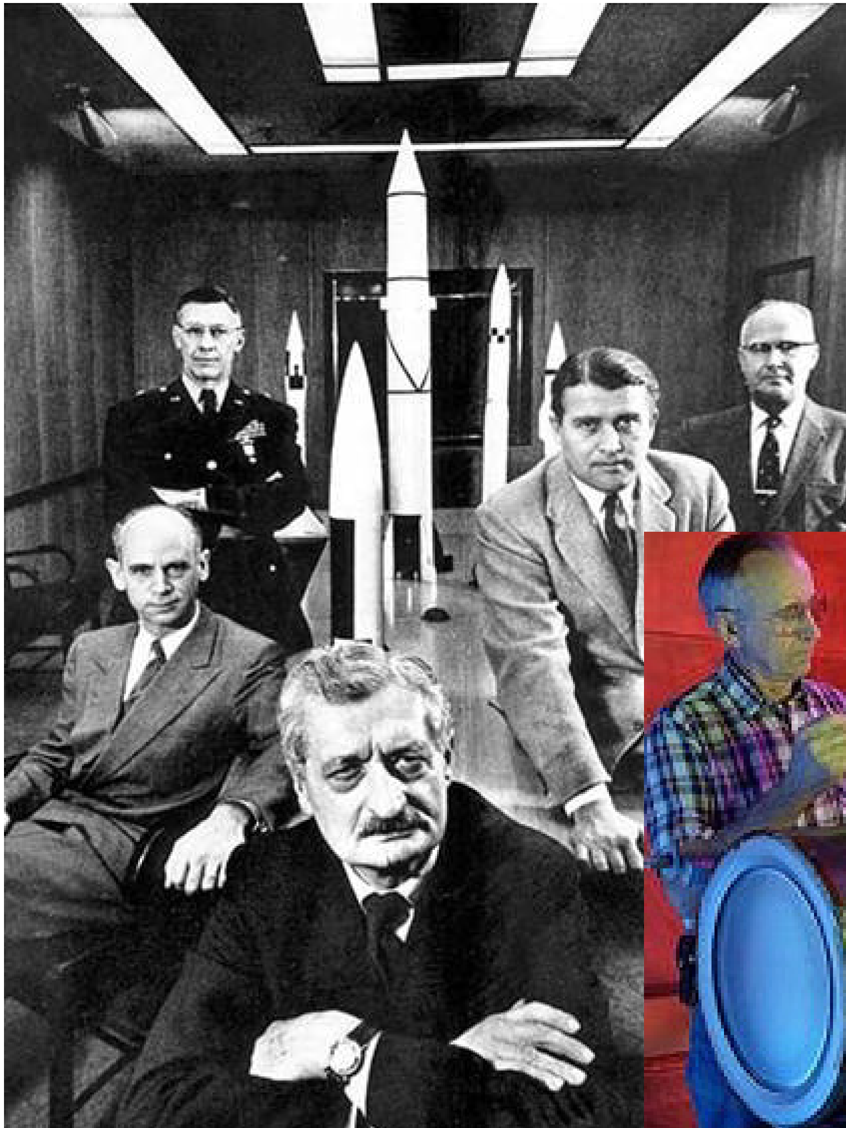
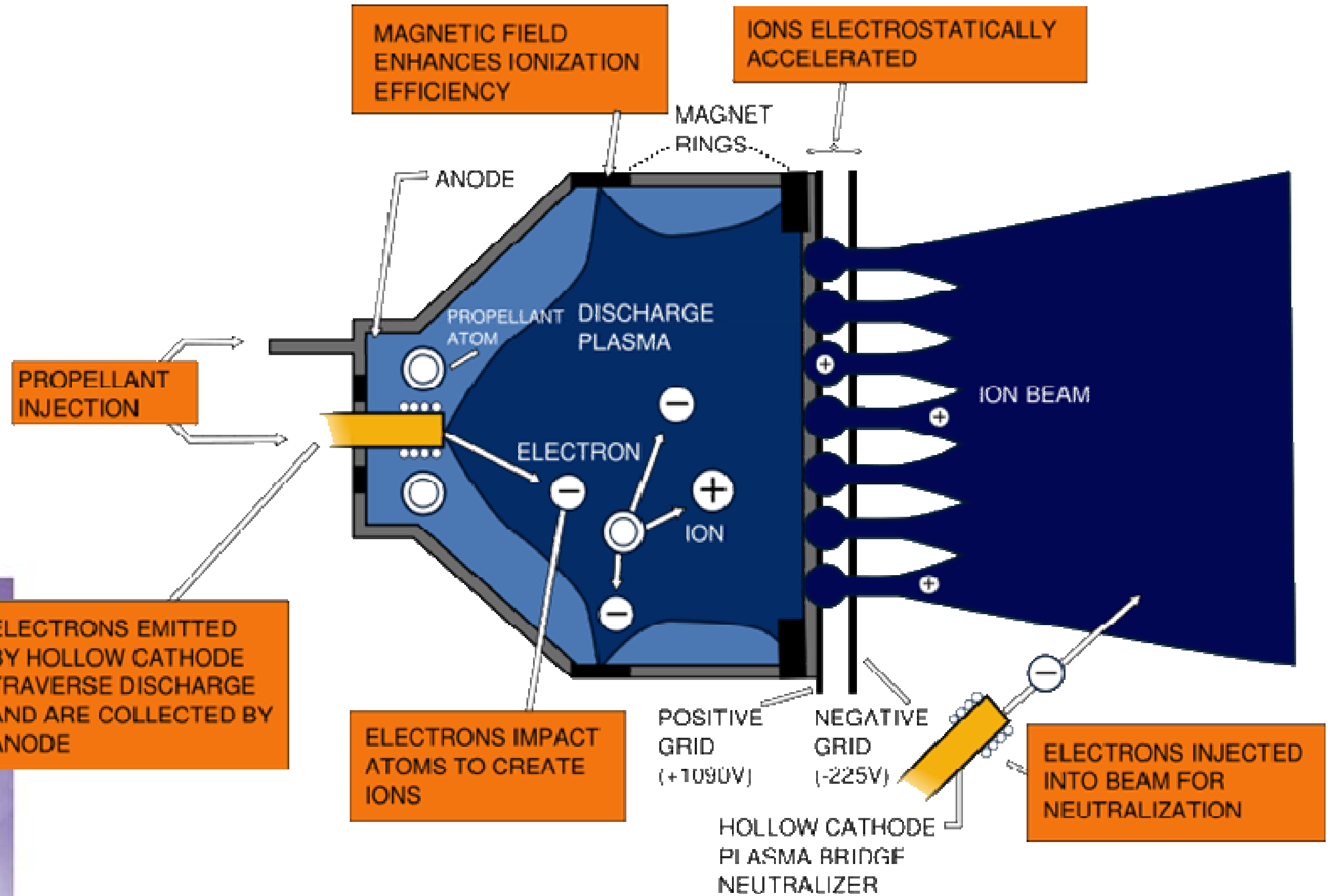
Herman Oberth and the ABMA rocket team (Early 1950s)




MAGNETIC FIELD ENHANCES IONIZATION EFFICIENCY
IONS ELECTROSTATICALLY ACCELERATED
MAGNET RINGS
ANODE
PROPELLANT ATOM
DISCHARGE PLASMA
PROPELLANT INJECTION
ELECTRON
ION
ION BEAM
ELECTRONS EMITTED BY HOLLOW CATHODE TRAVERSE DISCHARGE AND ARE COLLECTED BY ANODE
ELECTRONS IMPACT ATOMS TO CREATE IONS
POSITIVE GRID (+1090V)
NEGATIVE GRID (-225V)
HOLLOW CATHODE PLASMA BRIDGE NEUTRALIZER
ELECTRONS INJECTED INTO BEAM FOR NEUTRALIZATION

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Ion beam sputtering of optical coatings was invented by technologists at Litton in the early 1970s.

United States Patent [19] **Wei et al.**

[11] E Patent Number: **Re. 32,849**

[45] **Reissued** Date of Patent: **Jan. 31, 1989**

[54] **METHOD FOR FABRICATING MULTI-LAYER OPTICAL FILMS**

[75] Inventors: David T. Wei, Malibu; Anthony W. Louderback, Ojai, both of Calif.

[73] Assignee: Litton Systems, Inc., Woodland Hills, Calif.

[21] Appl. No.: 751,216

[22] Filed: Jul. 2, 1985

Related U.S. Patent Documents

Reissue of:

[64]	Patent No.:	4,142,958
	Issued:	Mar. 6, 1979
	Appl. No.:	896,133
	Filed:	Apr. 13, 1978

[51] Int. Cl.⁴ C23C 14/46

[52] U.S. Cl. 204/192.27; 204/298

[58] Field of Search .... 204/192 R, 192 C, 192 P, 204/298, 192.26, 192.27

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,247,392	4/1966	Thelen	250/226
3,835,032	7/1973	Schendrich	118/726
3,925,167	12/1975	Dermon	204/298
4,031,843	7/1977	Kirkham et al.	204/192 P
4,093,349	6/1978	Mills	350/641

OTHER PUBLICATIONS

W. D. Westwood et al, "Fabrication of Optical Waveguides by Ion Beam Sputtering", *J. Vac. Sci. Technol.*, vol. 13, pp. 104–106 (1976).

C. Misiano et al, "Co-Sputtered Optical Films," Vacuum, vol. 27, pp. 403–406 (1977).

W. Laznovsky, "Advances in Low-Energy Ion Beam Technology," *Research Development*, Aug. 1975, pp. 47–48, 50, 52, 54–55.

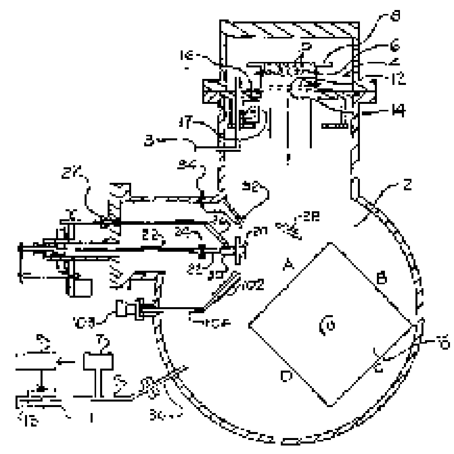
Primary Examiner—Aaron Weisstuch

Attorney, Agent, or Firm—Brown & Lorig

[57] **ABSTRACT**

A method for fabricating multiple layer interference optical films by ion beam sputtering, said films being used for mirrors in a ring laser apparatus. An ion beam strikes a target material obliquely, dislodging molecules of the target so that they can be deposited on a surface serving as a base for a multiple layer interference coating. The thickness of the coating is monitored so that the proper thickness of a given layer can be optimized to obtain the type of reflectance desired for a given light wave length. The surface to be coated is rotated during the deposition of the layer of target material. A stack of layers of alternating indices of refraction comprises the optical interference film. The coating process occurs inside of a vacuum chamber where the partial pressures of the gases are carefully controlled to insure the proper ion beam intensity and optimum stoichiometry of the deposited optical films. Prior to beginning the deposition of optical films, the ceramic substrate comprising the mirror base is bombarded by the ion beam at an oblique angle to remove surface anomalies and clean it.

22 Claims, 3 Drawing Sheets



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Technology

Ion Beam Sputtering

- Dense films (not porous)
- Excellent adhesion
- Stable and durable
- No spectral shift
- Low loss
- Easy to clean
- Indefinite lifetime

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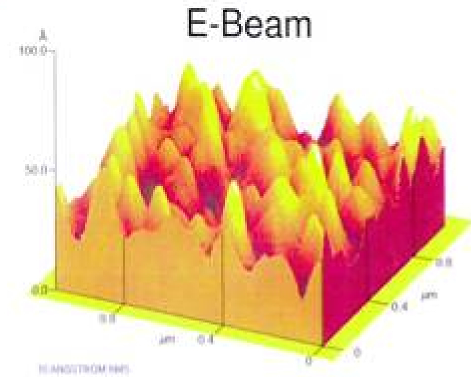
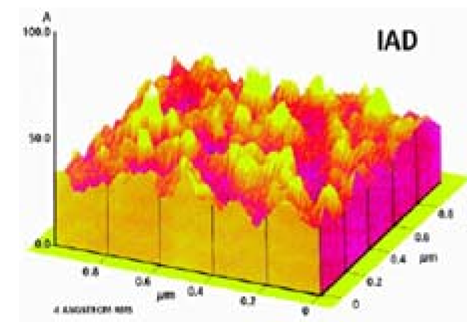
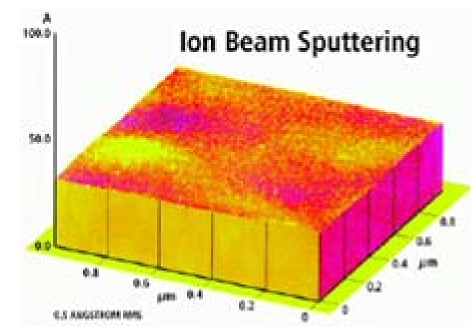
Comparison of E-beam evaporated, IAD, and IBS coatings



E-beam: Porous. Columnar structure. High scatter. Poor environmental stability.



IAD: Increased density. Reduced porosity. High stress. Improved environmental stability.



IBS: Dense films. Minimal structure. Low scatter. No porosity. Excellent environmental stability

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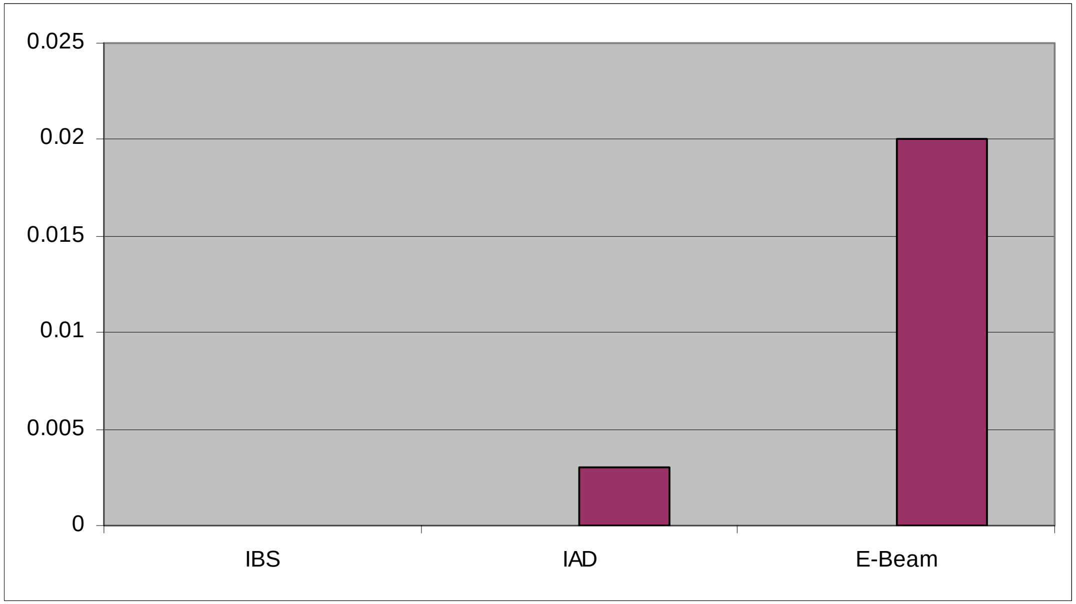
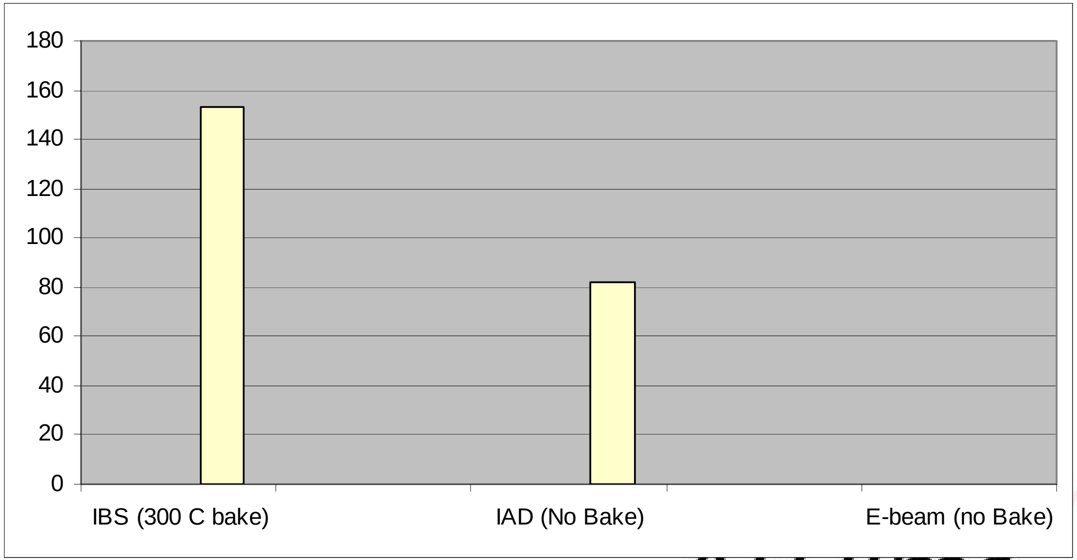
Spectral shift due to moisture (%).



Stress coefficient of mirror coatings (MPa).



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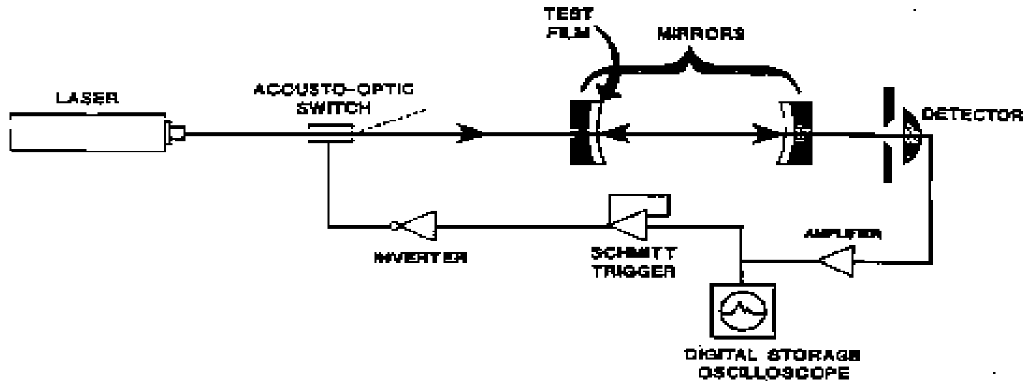

Figure 1: Instrumentation for cavity decay measurements.

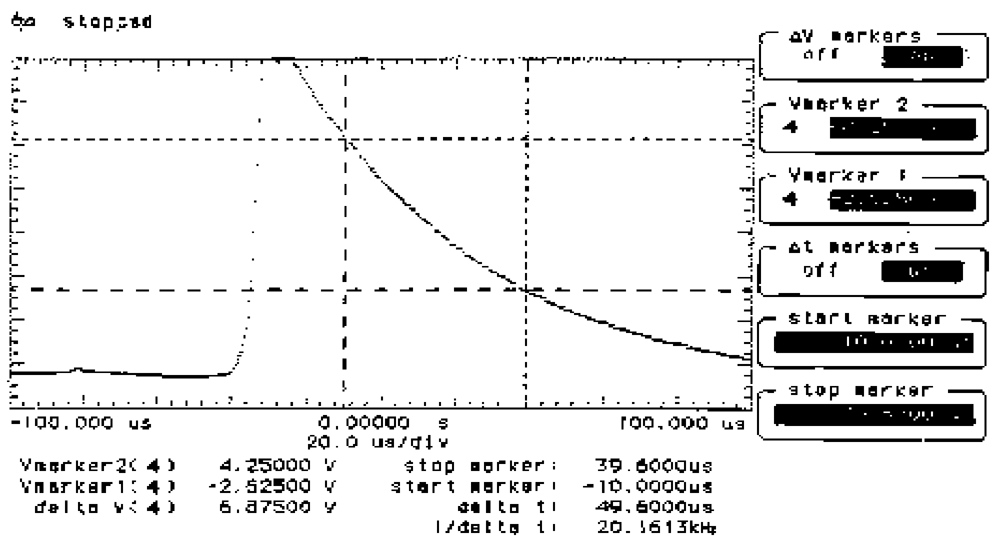

Figure 2: Oscilloscope output showing a decay curve.

Measured Losses

λ	material	Subs	Trans ppm	Total loss ppm	A&S ppm	measured by		
308nm	HfO2	ATF	1260	1795	535	Mark Yeo	CU	
369nm	Ta2O5	ATF-2.5cm	230	362	132	Andrew Grier	MIT	V4-664
369nm	Ta2O5	ATF-10cm	230	302	73	Andrew Grier	MIT	
405nm	Ta2O5	ATF	15	39	24	Steve Brown	NOAA	
514nm	Ta2O5	ATF	6	10	4	Steve Brown	NOAA	
635nm	Ta2O5	ATF	4	8	4	RL	ATF	V5-1 qualification
698nm	Ta2O5	GO	4	6	2	RL	ATF	V3-320 JILA Cavity
852nm	Ta2O5	ATF&REO	0.4	2.1	<2	Tracy Northup	Cal Tech	
1064nm	Ta2O5	GO	73	?	<0.5*	LIGO		* Absorption only
1392nm	Ta2O5	ATF	4	36	32	Tiger		Regular Process
1392nm	Ta2O5	ATF	4	7	3	Tiger		Low water films

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Materials which can be grown using IBS

Most oxides

Ta_2O_5, Nb_2O_5, V_2O_5, TiO_2, ZrO_2, HfO_2, Al_2O_3,Y_2O_3, SiO_2, …

Most nitrides

Si_3N_4, AlN, TiN, …

Most elements

Si, Al, Pt, …

IBS is generally not suitable for the deposition of fluorides and zinc compounds.

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Intrinsic Contaminants in IBS Films

1- Argon (working gas)

2- Water (typically the last element in the vacuum system)

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