Notes from TSC-1 Meeting

19 October 2021

TSC-1 Meeting called to order by Brian Lund, Chair at 10:15 AM CDT. Robert Thomas was present as secretary, and Vice Chair (David Sliney) was present at the meeting. A complete listing of attendees is attached.

Agenda presented:

- Status of Z136.1 Revision (B. Rockwell)
- Procedures for Submitting Input to SSC-1 (R. Thomas)
- Revisions to UV Ocular and Skin MPEs (B. Lund)
- (Amended) Sub-ns MPE Analysis (J. Lund)
- Added: Robert Aldrich – Addition of Control Groups for HEL – Tabled by Brian Lund

■ C.D. Clark – Motion to Approve Agenda, Robert Aldrich 2nd. Approved without objection.

■ Dr. Lund presented current membership listing. Jacqueline Ansa (guest supporting LIA). Stephen Wengraitis and Adam Carlisle joined as a guests (observers).

■ Dr. Rockwell discussed the status of Z136.1 standard revision. The CDV 3 recirculation (CDV 4) ballot will be provided soon to the main committee of ASC Z136. The revision will resolve substantive changes from the public review and comments.

■ Robert Thomas discussed the need to capture position or positions regarding the TSC-1 recommendations for revisions in the Z136.1 exposure limits and other related materials. The timing of this artifact submission was discussed. Dr. Rockwell recommended a time approximately two years from now for an initial set of documented recommendations, during the Z136.1 revision SCDV formation process. The TSC-1 is now looking toward the next version of the Z136.1 and should formulate an approach for the content agenda recommendations and a form for the documentation of potential recommendations. Dr. Clark recommended an incremental approach based upon individual meetings and their minutes. Jay Parkinson noted that the ICNIRP guidelines (Health Physics Publication) are a good reference when contributing to standards. Dr. Sliney noted that there are few known significant revision pending, based upon recent research findings.

■ CD Clark motioned to add Jack Lund's presentation to the agenda, seconded by Robert Thomas and was approved without objection.

■ David (Jack) Lund provided a talk on sub-ns exposure limit revisions. Jack has presented the information at a recent ILSC (2019). The analysis of time-dependence of exposures from 10^{-14}-10^{4} seconds was reviewed. He presented a summary of the comparison of his analytical model to current exposure limits (a mathematical equation fitting formulation). The exposure limits have discontinuities in time, where his approximation (good to about a factor of two compared to experimental data presented). There are locations at 532nm and 1064nm in his analysis where safety margin dips to a range of 2.3 – 3.2, depending on the wavelength near 10^-10 to 10^-11 seconds. Mr. Lund has

examined potential shifts in step functions in the time-dependence of the exposure limit definitions. He followed the initial "curve fitting" analysis with an action spectrum approach for the wavelength dependence, based upon optical properties of ocular components. The model has disagreement with experimental data in the near infrared (>1000 nm). Presented were potential modifications to C_A and C_c factors used in the MPE definitions. Detailed recommendations are available in slides provided. Mr. Aldrich questioned the historical significance of decreasing exposure limits. The impact is primarily for short pulse lasers that are less than 500 ns and less than 550 nm. Dr. Sliney questioned the accuracy of the fitting functions at shorter wavelengths. Dr. Rockwell asked about data on injuries and the specifics of where limits would change. Dr. Clark also questioned with respect to current assumptions regarding t_{min}. Dr. Schulmeister reminded the team that the most recent revisions were based upon high quality data and that the proposed changes may have further-ranging impacts for 0.25 seconds and affect a broad range of products/system. His position is that current safety margins are sufficient. Dr. Shulmeister also noted agreement with changes in near-IR. Dr. Rockwell noted that his research team has data regarding very short pulse between 532nm and 1064nm (model of self-focusing). He is referencing a paper that is in peer review and will provide the citation: Benjamin A. Rockwell, Robert J. Thomas, Alfred Vogel, Ultrashort laser pulse retinal damage mechanisms and their impact on thresholds, Medical Laser Application, Volume 25, Issue 2, 2010, Pages 84-92, ISSN 1615-1615, https://doi.org/10.1016/j.mla.2010.02.002.

- Dr. Brian Lund provided an overview of UV Ocular and Skin MPEs as they currently appear in the Z136.1 draft document. There was a difference in the UV where skin MPEs were not divided in time (or extended in time) in the same manner as ocular MPEs. There are ranges where skin MPEs are lower than ocular MPEs due to these time-wavelength factors. A small working group examined these carefully (sub-group of TSC-1). The table errors were addressed by the TSC-1 chair subsequent to the public review process and the corrections are part of current review of CDV 4 of the Z136.1 document. A significant aspect of the change is moving several sub-ns exposure limits to thermal column, recognizing that they are ablative mechanisms in nature. Detailed slides are provided as an attachment. Dr. Lund provided a summary of not only updated tables of MPEs, but also Section 8 revisions and related figures that summarize the exposure limits as graphs. Dr. Sliney has a paper summarizing the incoherent vs laser exposure limits. (Schulmeister et al, "Review of exposure limits and experimental data for corneal and lenticular damage from short pulsed UV and IR laser radiation," J. Laser Applications 20 (2), (2008)). Dr. Lund noted that some changes are errata, while some changes are for consistency between ocular and cornea/skin exposure limits. Dr. Sliney and Chris Brumage discussed sources of data and relative risks of areas of the body exposed. Dr. Sliney provided figures from a 2021 paper that summarized the basis of changing trends in MPEs from 180 to about 270 nm. (Sliney and Stuck, "A Need to Revise Human Exposure Limits for Ultraviolet UV-C Radiation," Photochemistry and Photobiology 97, 485-492 (2021). Robert Thomas asked about harmonization with other standards. Dr. Schulmeister noted that IEC standards group will pick up eventual ICNIRP recommendations, but that working group has not been formed to begin such a work project. It was noted that incoherent limits (ACGIH, etc.) do not span the exposure duration range of down to 100fs. Dr. Lund asked if Dr. Rockwell as SSC-1 vice chair could recommend a formal ballot from the TSC-1 regarding the recommendation. Dr. Rockwell asked about current data and concerns regarding potential future revisions of exposure limits. Dr. Sliney noted that some of these errors were present in earlier drafts. Liliana (representing secretariat) asked if SSC-1 ballot on Z136.1 revisions should be held until the team can review. Dr. Lund

noted that the Z136.ORG site (TSC-1 Area) has a number of notes from past deliberations. Dr. Sliney contended that these definitions were previously approved by the TSC-1. Brian Lund asked for motion to approve (David Sliney Motioned to approve and Jay Parkinson seconded the motion). The TSC-1 meeting minutes of 19 March 2019 reflect that the topic was discussed (Dr. Hunter chaired that meeting). The motion to accept the MPE definitions as presented was approved without objection. Dr. Brian Lund will provide documentation to the SSC-1 Chair as an action.

- Dr. Jennifer Hunter's topic, initially proposed for the agenda is tabled until the next meeting.

At 12:55 PM CDT, Dr. Brian Lund called for a motion to adjourn. Dr. Clark motioned for adjourned, with Dave Sliney seconding. The motion was approved without objection. The group adjourned at 12:36 PM CDT.

Minutes prepared by Dr. Robert Thomas, Secretary. Meeting held via Zoom teleconference and was recorded by LIA.

Attachment 1: Attendance Roster, TSC-1 Meeting, 19 October 2021

Last Name	First Name	Email
Aldrich	Robert	raldrich@acc4u.com
Brennan	James	jamesfbrennan@att.net
Brumage	Chris	chris.brumage@gmail.com
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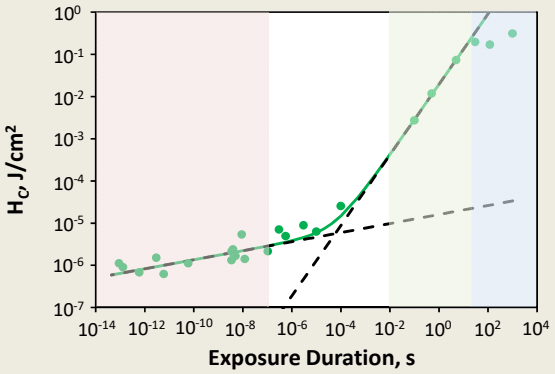
Clark	Clifton D.	cdclark@fhsu.edu
Denton	Michael	michael.denton.10@us.af.mil
Flores-McLaughlin	John	john_fm@icloud.com
Henes	Yuliya	yuliya.henes@wisc.edu
Kang	Robert	rkang79@gmail.com
Kelly	Ed	kelly.ed@ieee.org
Lund	Brian	blund@satx.rr.com
Lund	David (Jack)	jacklund@satx.rr.com
Luviano	Damien	damien.luviano@va.gov
Marshall	Wes	Wesmarshall_2000@yahoo.com
McHatton	Roberta	ROBERTA@LASERSAFETYSERVICES.COM
O'Hagan	John	john.ohagan@phe.gov.uk
Parkinson	Jay	jay@lasersafetyconsultant.com
Rockwell	Ben	benjamin.rockwell@us.af.mil
Sahler	Ruth	ruth@sahler.org
Schulmeister	Karl	karl.schulmeister@seibersdorf-laboratories.at
Sliney	David	david.sliney@att.net
Sparks	Shawn	lasers@ssparks.com
Stanley	Christine	(observer)
Stuck	Bruce	bstuck@satx.rr.com
Thomas	Robert	robert.thomas.47@us.af.mil
Wengraitis	Steve	(observer)
LIA Representatives		
Ansa	Jacqueline	(LIA)
Calera	Liliana	(LIA)

Time Dependence of Laser-Induced Thermal Retinal Injury

Jack Lund
Consulting Biophysicist

Background & Methods



Photochemical

Thermal photocoagulation

- Thermal denaturation of proteins

Transition

- Interaction of mechanisms

Thermal confinement

- Microcavitation/shock wave
- Self focusing
- Light induced breakdown

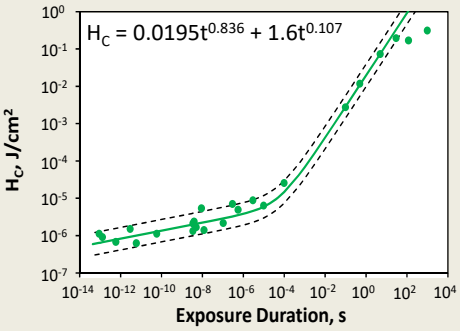
Fit a regression line to the thermal photocoagulation data. $H_C = 0.0195t^{0.836}$

Fit a regression line to the thermal confinement data. $H_C = 1.6t^{0.107}$

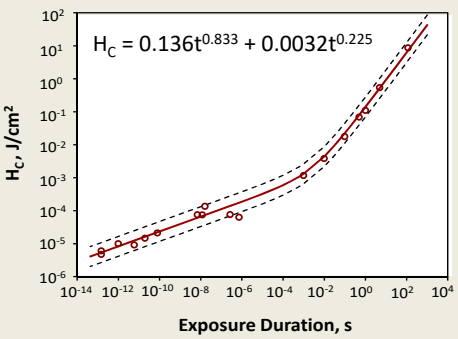
Let the fit to the data be the sum of these two lines. $H_C = 0.0195t^{0.836} + 1.6t^{0.107}$

In vivo ED_{50} data for green and NIR laser exposure

532 nm



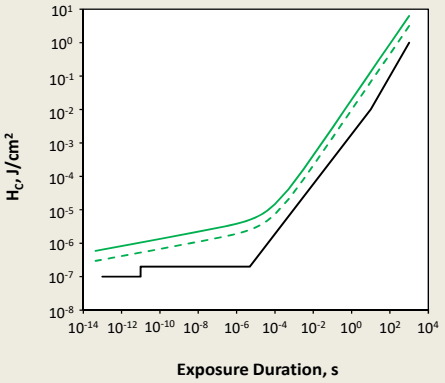
1064 nm



Solid line is the fit to the ED_{50}data. Dotted lines are at 2X the ED_{50} fit and 1/2 the ED_{50} fit. Most data points fit within this range.

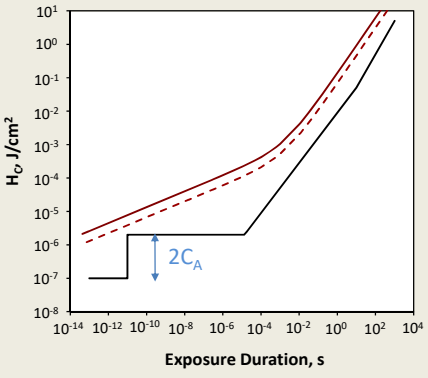
Comparison to the MPE

Green wavelength lasers

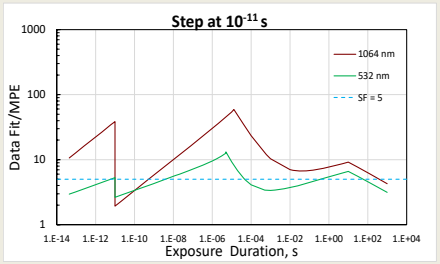


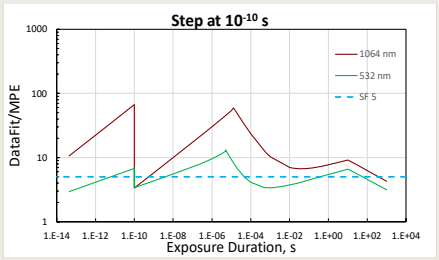
Safety margin is 3.2 at 10^{-11} seconds
Safety margin is 14.5 at 5 X 10^{-6} seconds

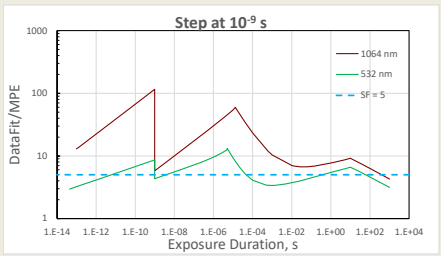
1060 nm lasers

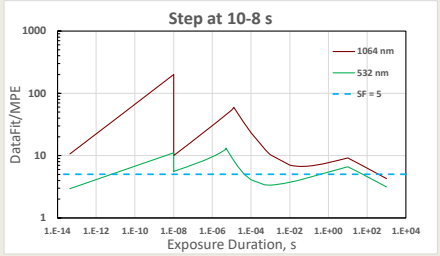


Safety margin is 2.3 at 10^{-11} seconds
Safety margin is 47.3 at 5 X 10^{-6} seconds



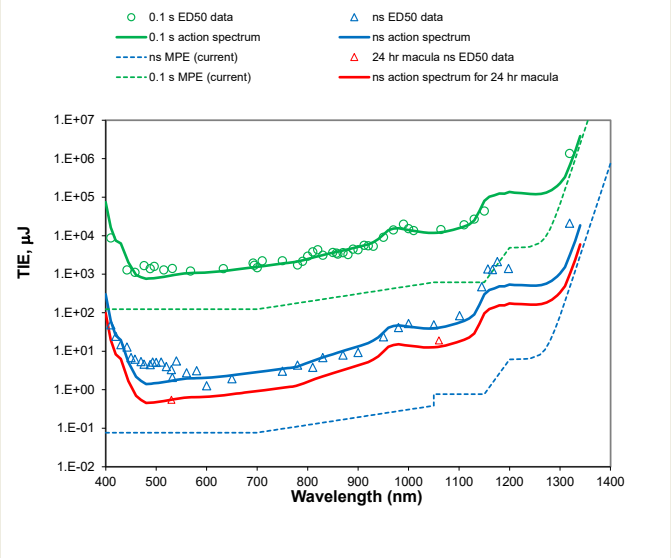






Shown are the safety margins (SF) as they vary with the position of the step. The dotted blue line represents a safety margin of 5. The step would need to be moved to 10^{-9} or 10^{-8} s provide a safety margin of 5 over most of the short-pulse regime.

Action spectrum



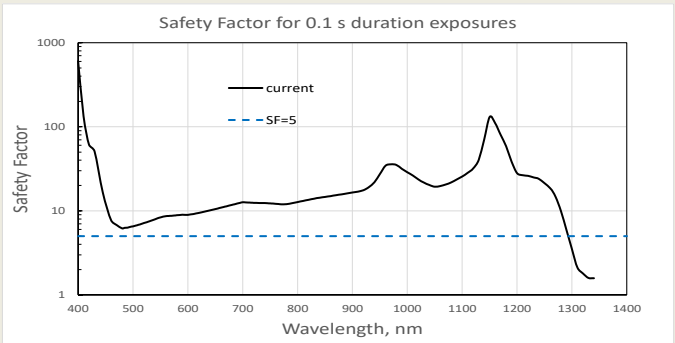
$$TIE(\lambda) = k \cdot (D_\lambda^X / (T_\lambda \cdot Tb_\lambda \cdot A_\lambda)$$

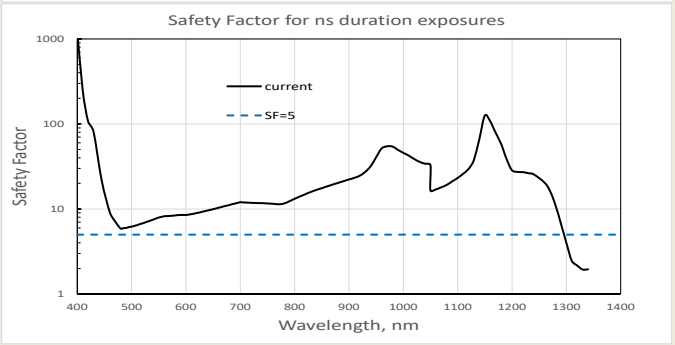
D_λ = retinal irradiation diameter (Chromatic aberration induced)

T_λ = transmission of ocular media

Tb_λ = transmission of 5 µm of blood

A_λ = absorption in RPE





Suggested changes to C_A and C_C

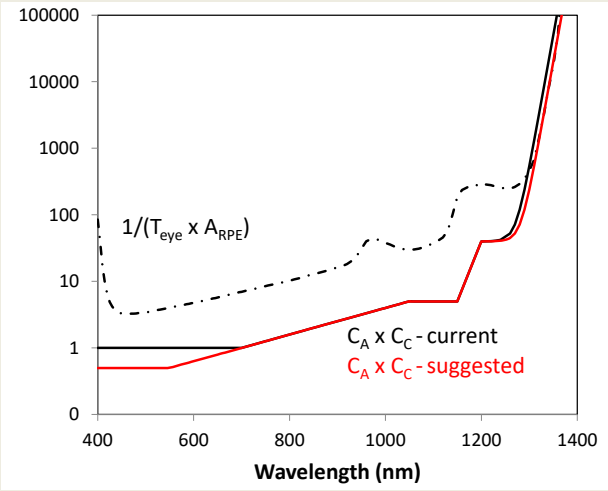


Table 6a - current

C_A	1.0	400 to 700
	$10^{0.002(\lambda-700)}$	700 to 1050
	5.0	1050 to 1400

C_C	1.0	1050 to 1150
	$10^{0.018(\lambda-1150)}$	1150 to 1200
	$8 + 10^{0.04(\lambda-1250)}$	1200 to 1400

Table 6a - suggested

C_A	0.5	400 to 550
	$10^{0.002(\lambda-700)}$	550 to 1050
	5.0	1050 to 1400

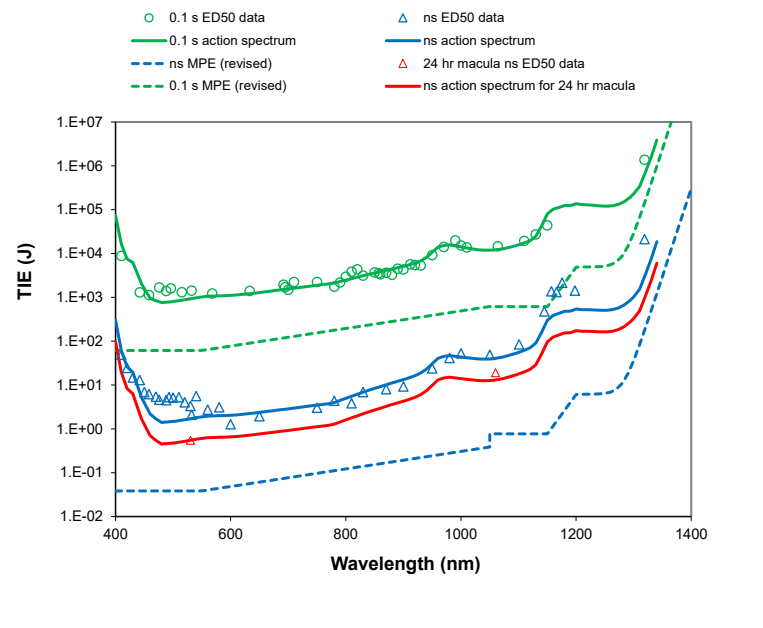
C_C	1.0	1050 to 1150
	$10^{0.018(\lambda-1150)}$	1150 to 1200
	$8 + 10^{0.04(\lambda-1260)}$	1200 to 1400

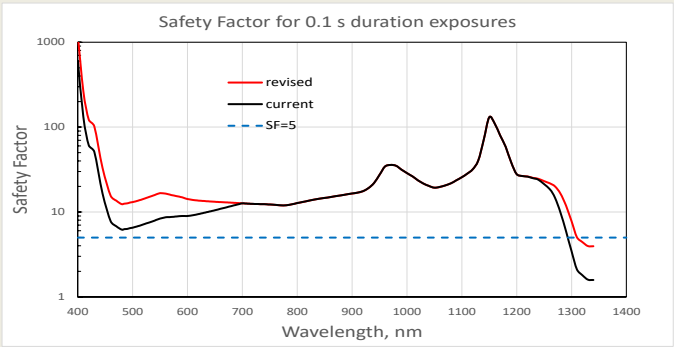
Table 5b - current

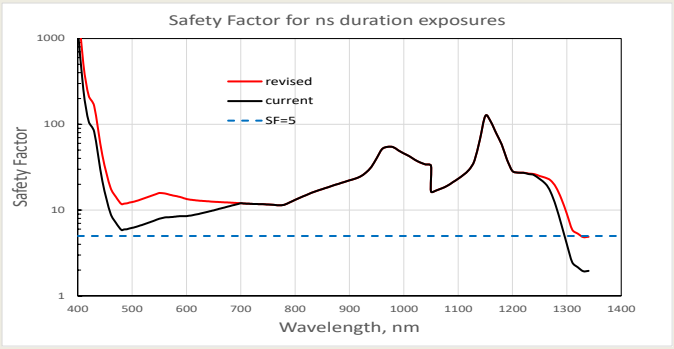
500 to 700	10^{-13} to 10^{-11}	1.0×10^{-7}	-
	10^{-11} to 5×10^{-6}	2.0×10^{-7}	-
	5×10^{-6} to 10	$1.8\, t^{0.75} \times 10^{-3}$	-
	10 to 30,000	-	1×10^{-3}

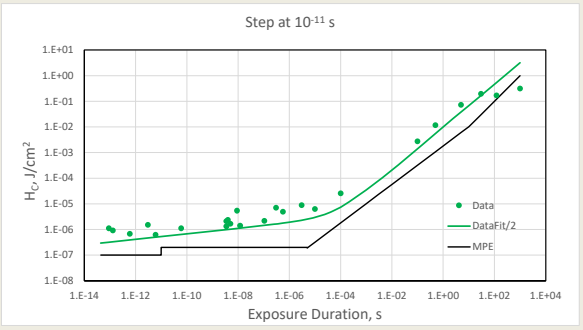
Table 5b - suggested

500 to 700	10^{-13} to 10^{-11}	1.0×10^{-7}	-
	10^{-11} to 5×10^{-6}	$2.0\, C_A \times 10^{-7}$	-
	5×10^{-6} to 10	$1.8\, C_A t^{0.75} \times 10^{-3}$	-
	10 to 30,000	-	$C_A \times 10^{-3}$



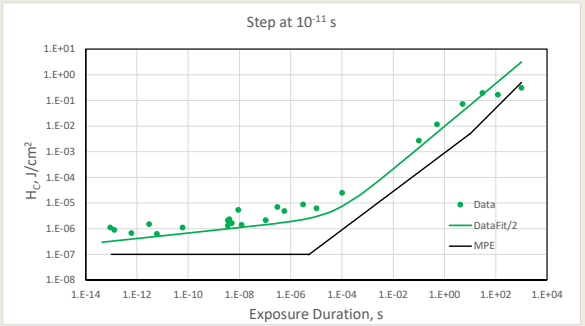


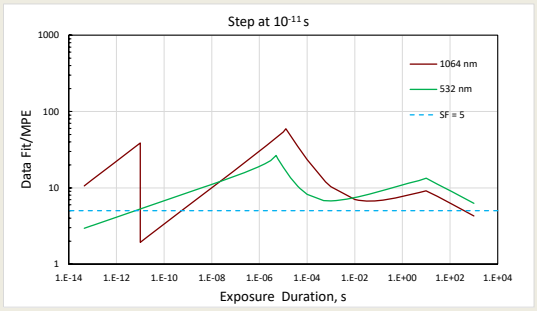




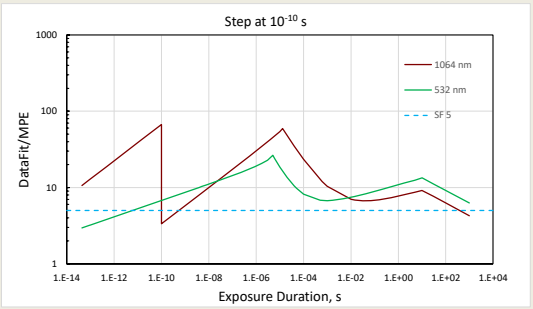
Data compared to current MPE

Data compared to suggested MPE





Safety margins (SF) with suggested change to C_A and C_C



Influence of ocular axial length on retinal damage thresholds from 100-millisecond near-infrared laser radiation exposure at 1319 nm

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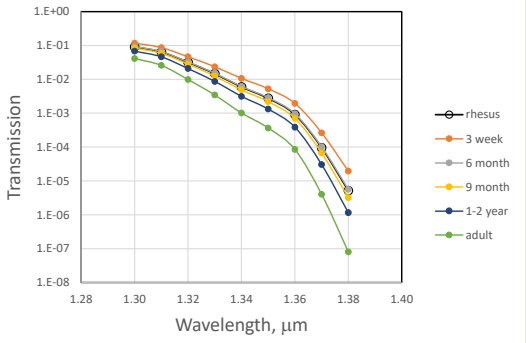
University of Bergen, School of Medicine,
Department of Ophthalmology
(Head: Professor Torstein I. Bertelsen, M.D.)

THE SAGITTAL GROWTH OF THE EYE
IV. Ultrasonic measurement
of the axial length of the eye from birth to puberty

BY

JON S. LARSEN

Refractive development of the human eye.
RA Gordon and PB Denzis.
Acta Ophthalmol 103:785-789 1985



Transmissions calculated using data of CIE TC6-15

Measured MVL thresholds for 1319 nm laser exposures in NHP eye with extrapolated MVL thresholds in young and mature human eye

		Duration = 80 ms			Duration = 20 ns		
		Rhesus ED_{50} = 11.1 W			Rhesus ED_{50} = 0.021 J		
		Rhesus ED_{50} = 0.89 J					
		MPE = 0.33 J		abberation	MPE = .00049 J		abberation
		ED_{50}		corrected	ED_{50}		corrected
	Teye	J	SF	SF	J	SF	SF
adult	0.010	2.89	8.75	4.25	0.068	139	33
1-2yo	0.021	1.36	4.13	2.01	0.032	66	15
3 week	0.046	0.61	1.86	0.90	0.014	29	7
rhesus	0.032	0.89	2.70	1.31	0.021	43	10

ED_{50}(adult) = ED_{50}(rhesus) x T(rhesus)/T(adult)
ED_{50}(1-2yo) = ED_{50}(rhesus) x T(rhesus)/T(1-2yo)
ED_{50}(3 week) = ED_{50}(rhesus) x T(rhesus)/T(3 week)

Chromatic abberated spot size 175 μm
accomodated spot size 85 μm
abberation corrected ED_{50} = 85/175 x abberated ED_{50} for ms exposures
abberation corrected ED_{50} = $(85/175)^2$ x abberated ED_{50} for ns exposures