INTRODUCTION

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OPTICAL PROPERTIES OF TISSUES *IN VITRO*

Tissue	λ (nm)	μ_t cm^{-1}	μ_a cm^{-1}	μ_s cm^{-1}	$\mu_s(1-g)$	g	μ_{eff} cm^{-1}	Tissue Preparation and geometry	Experimental method	Theory (Inverse form)	Reference
Adipose											
Cow	632.8	—	—	—	—	—	3.4	in situ, slabs	interstitial fiber detectors	Diffusion Theory	Preuss *et al.*, 1982
Pig	630	376±69	—	—	—	0.77	—	ground, frozen, thawed, thin slab	direct T[a], goniophotometry	Beer's Law Mie theory	Flock *et al.*, 1987
	630 789	— —	0.1 0.06	— —	15.4 13.6	— —	2.2 1.6	*in situ*, ~5 cm^3	interstitial cylindrical source and flat fiber detectors	Grosjean's model, '56 (spherical geometry)	Arnfield *et al.*, 1992
Aorta											
Human • normal	308	—	33	—	77	—	104	*post mortem* (6h), excised, in 4°C saline, used within 1 h, slab	60 ns 308 laser pulses; optical multichannel analyzer to isolate 308 nm line; integrating sphere	Adding-Doubling	Oraevsky *et al.*, 1992.
• fibrous plaque	308	—	24	—	81	—	87				
• normal	632.8	316	0.52	316	41.0	0.87	8.0	*post-mortem*, resected, in saline, slab	integrating sphere, gonio-photometry	Diffusion Theory, fit asymptotic T + HG[b]	Yoon *et al.*, 1988
	1064 (1)	—	0.5	239	23.9	0.9 [c]	6.0	*post-mortem*, slab	(1) integrating sphere and goniophotometry (2) integrating sphere only	(1) Monte Carlo [Piet, 1992] (2) Diffusion Theory (∂-Eddington) [Prahl 1988]	(1) Essenpreis, 1992 (2) Cheong, 1990
	(2)	—	0.7	—	22.4	—	7.0				
	1320 (1)	—	2.2	233	23.3	0.9 [c]	13.0	— as (1) above —	— as (1) above —	— as (1) above —	— as above —
	(2)	—	4.3	—	17.8	—	11.8	— as (2) above —	— as (2) above —	— as (2) above —	— as above —
Human • fibro-fatty	355 532 1064	— — —	17.7 3.6 0.09	— — —	64.9 24.8 7.7	— — —	66.1 20.4 1.45	*post-mortem*, resected, slab usedwithin 24 h.	photoacoustic transducer to detect shape + peak amplitude of laser-induced pressure wave.	Acoustic Theory	Oraevsky/Jacques1993
normal intima	476 580 600 633	252 191 182 175	14.8 8.9 4.0 3.6	237 183 178 171	45.0 34.8 33.8 25.7	0.81 0.81 0.81 0.85	— — — —	post-mortem, frozen, sliced into thin slabs, thawed	integrating sphere and direct T measurements	Diffusion Theory (delta-Eddington)	Keijzer *et al.*, 1989
normal media	476 580 600 633	252 191 182 312	7.3 4.8 2.5 2.3	410 331 323 310	45.1 33.1 35.5 31.0	0.89 0.90 0.89 0.90	— — — —	— as above —	— as above —	— as above —	Keijzer *et al.*, 1989
normal adventitia	476 580 600 633	252 191 182 201	18.1 11.3 6.1 5.8	267 217 211 195	69.4 49.9 46.4 37.1	0.74 0.77 0.78 0.81	— — — —	— as above —	— as above —	— as above —	Keijzer *et al.*, 1989

[a] T=transmission; R=reflection

[b] HG=Henyey-Greenstein phase function

[c] From reference #155 in Essenpreis, 1992

Tissue	λ (nm)	μ_t cm^{-1}	μ_a cm^{-1}	μ_s cm^{-1}	$\mu_s(1-g)$	g	μ_{eff} cm^{-1}	Tissue Preparation and geometry	Experimental method	Theory (Inverse form)	Reference
Pig aorta	1060	—	0.33	—	20.1	—	—	resected, in saline, used within 24 h, slab	double integrating spheres (excl. sphere corrections)	Diffusion Theory (delta-Eddington)	Cheong, 1990
	1320	—	1.5	—	18.3	—	—				
Biliary Caculi (Gallstones)											
Porcinement	351	—	102±16	—	—	—	—	dehydrated, embed in plastic, sliced into ~1 mm slabs	staring infrared detector measures thermal response time	pulsed photothermal radiometry (PPTR)	Long *et al.*, 1987
	488	—	179±28	—	—	—	—				
	580	—	125±29	—	—	—	—				
	630	—	85±11	—	—	—	—				
	1060	—	121±12	—	—	—	—				
Cholesterol	351	—	88± 7	—	—	—	—	—— as above ——	———— as above ————	——— as above ———	Long *et al.*, 1987
	488	—	62±15	—	—	—	—				
	580	—	36± 7	—	—	—	—				
	630	—	44±10	—	—	—	—				
	1060	—	60± 9	—	—	—	—				
Bladder											
Dog	633 (1)	—	0.6	59	—	0.85	—	resected, in saline < 24 h, slab	(1) interstitial fiber detection in situ (spherical field)	(1) van de Hulst solution	(1) Star *et al.*, 1987b
	(2)	—	1.25	44	—	0.92			(2) integrating sphere	(2) Diffusion Theory	(2) Cheong *et al.*, 1987
	1064	—	0.25	—	3.2	0.962 [d]	—	resected, in saline < 12 h, slab	two integrating spheres, direct T (excl. sphere corrections)	Diffusion Theory (delta-Eddington)	Cheong, 1990
	1320	—	1.3	—	2.4	0.962	—				
Blood (Whole)											
Human, Hct=0.41 oxygenated	665 (1)	1247	1.30	1246	6.11	0.995	—	diluted, heparinized, in cuvettes	(1) absorbance+goniometry	(1) Mie Theory	(1) Reynolds *et al.*, 1976
	960	508	2.84	505	3.84	0.992	—				
	685 (2)	1416	2.65	1413	—	0.990	—		(2) radial reflectance profile	(2) Transport Theory	(2) Pedersen *et al.*, 1976
Hct=0.47 partially oxygenated	450	3320	381	2940	8.3	0.9972	668	freshly drawn, heparinized, oxygenated at atmospheric equilibrium; semi-infinite slab (R_d); thin cuvettes (μ_a, μ_t)	diffuse R of whole blood; direct T of diluted blood, hemolyzed RBC's, and centrifuge-isolated plasma.	Inverse Adding-Doubling and Beer's Law	Jacques, 1993a
	488	3330	133	3190	4.0	0.9987	235				
	514	3430	116	3320	4.1	0.9988	206				
	577	3440	301	3140	7.3	0.9977	528				
	630	3670	14.3	3660	8.9	0.9976	31.6				
	760	2840	15.5	2820	7.9	0.9972	33.0				

[d] g-value taken from 1320 nm data

Tissue	λ (nm)	μ_t cm^{-1}	μ_a cm^{-1}	μ_s cm^{-1}	$\mu_s(1-g)$	g	μ_{eff} cm^{-1}	Tissue Preparation and geometry	Experimental method	Theory (Inverse form)	Reference
Blood (Whole)											
Dog	632.8	—	—	—	—	0.9845	—	heparinizedwhole blood, in cuvettes	goniophotometry	fit to 2-parameter phase function [Reynold *et al.*, 1980]	Steinke *et al.*, 1988
	660	—	—	—	—	0.9840	—				
	800	—	—	—	—	0.980	—				
Blood clots											
Canine: arterial	1060	—	5.5±1.6	—	9.6±2.0	—	—	thrombin added to freshly drawn blood, in thin rectangular glass holders	double integrating spheres, direct T at 1320 nm only, (incl. sphere corrections)	Diffusion Theory and Beer's Law	Cheong, 1990
	1320	—	1.6±1.7	—	10.0±2.7	0.93±.02	—				
venous	1060	—	5.4±3.9	—	9.2±3.6	—	—				
	1320	—	1.9±.8	—	9.5±3.2	0.93±.06	—				
Brain											
Calf	633	—	0.19	—	6.6	—	2.5[(1)]–3.4	frozen, sliced into slabs and thawed	integrating sphere (μ_a,μ_s'); interstitial detectors (μ_{eff})	Similarity transform, 2-parameter phase; (1) Diffusion Theory	Karagiannes *et al.*, 1989; (1) Doiron *et al.*, 1983
	1064	—	0.36	—	6.7	—	2.5				
	1320	—	0.84	—	5.4	—	4.0				
Cat	488	—	—	—	—	—	10.9	*post mortem,* bulk tissue	interstitial flat cut fiberoptic detectors	Diffusion Theory	Doiron *et al.*, 1983
	514.5	—	—	—	—	—	13.3				
	630	—	—	—	—	—	5.3–8.9				
Human: • Adult	488	—	—	—	—	—	14.0-25.0	post-mortem, blood vessels not saline-irrigated, *in situ*	interstitial source and fiber detectors	Diffusion Theory	Svaasand *et al.*, 1983
	514	—	—	—	—	—	14.0-16.7				
	660	—	—	—	—	—	7.0-12.5				
	1060	—	—	—	—	—	2.3-3.4				
	630	—	0.3-1.0	—	30.0–40.0	—	8.3	*post-mortem,* slab	integrating sphere, direct T	Diffusion + Kubelka Munk Theories	Sterenborg *et al.*, 1989
• Neonate	488	—	—	—	—	—	5.9-7.9	post-mortem, blood vessels not saline-irrigated, *in situ*	interstitial source and fiber detectors	Diffusion Theory	Svaasand *et al.* [1983]
	514	—	—	—	—	—	5.8-9.0				
	660	—	—	—	—	—	2.5-3.3				
	1060	—	—	—	—	—	1.1-1.4				
• Adult white mater	632.8		2.2±.2	532±41	91±5	0.82±.01	23.8±1.4	freshly resected, used within 12h; slabs (1<t<10)	integrating sphere, direct T (include sphere corrections)	Inverse Adding-Doubling	Beek *et al.*, 1993a
	1064		3.2±.4	469±34	60.3±2.5	0.87±.007	24.1±1.7				
• Adult grey mater	632.8		2.7±.2	354±37	20.6±2.	0.94±.004	13.3±.9				
	1064		5.0±.5	134±14	11.8±.9	0.90±.007	15.7±1.3	— as above —	——— as above ———	—— as above ——	—— as above ——
Pig	633	0.26-0.64		52-57		0.945 (1)	4.3-14.2	*post-mortem,* bulk; (1) frozen, cut, thawed	interstitial fiber detectors; (1) goniophotometry (g)	Diffusion Theory / "Added Absorber"; (1) Mie theory	Wilson *et al.*, 1985, 1986a; Preuss *et al.* 1982; (1) Flock *et al*, 1987

Tissue	λ (nm)	μ_t cm^{-1}	μ_a cm^{-1}	μ_s cm^{-1}	$\mu_s(1\text{-}g)$	g	μ_{eff} cm^{-1}	Tissue Preparation and geometry	Experimental method	Theory (Inverse form)	Reference
Breast											
Glandular	540 700 900	— — —	3.6±2 0.5±.1 0.6±.1	— — —	24±6 14±3 10±2	— — —	— — —	frozen sections, thawed; 4-24 µm slabs for μ_t; ~ 1 mm slabs for (R,T)	single integrating sphere with monochromator for R and T; 2-polarizers to filter scattered axial light for direct T.	Monte Carlo; look up tables of (R,T) as function of albedo, g, and μ_t	Peters *et al.*, 1990
Adipose	540 700 900	— — —	2.3±.6 0.7±.1 0.8±.1	— — —	10±2 9±1 8±1	— — —	— — —	—— as above ——	—— as above ——	—— as above ——	Peters *et al.*, 1990
Fibrocystic	540 700 900	— — —	1.6±.7 0.2±.1 0.3±.1	— — —	22±3 13±2 10±2	— — —	— — —	—— as above ——	—— as above ——	—— as above ——	Peters *et al.*, 1990
Fibroadenoma	540 700 900	— — —	4.4±3 0.5±.5 0.7±.5	— — —	11±3 7±2 5±1	— — —	— — —	—— as above ——	—— as above ——	—— as above ——	Peters *et al.*, 1990
Ductal carcinoma	540 700 900	— — —	3.1±1 0.5±.1 0.5±.2	— — —	19±5 12±3 9±3	— — —	— — —	—— as above ——	—— as above ——	—— as above ——	Peters *et al.*, 1990
Cartilage						—	—				
Rabbit	632.8	—	0.33±.05	214±.2	19.4±1.1	0.909±.005	4.4±.4	freshly resected, used within 12h; slabs (1<t<10)	two integrating spheres , direct T (incl. sphere corrections)	Inverse Adding-Doubling	Beek *et al.*, 1993a
Esophagus											
Human	632.8	—	0.4	—	12	—	—	2.5 mm slab	integrating sphere	Adding-Doubling	Jacques, 1993b
Kidney											
Cow	630	—	—	—	—	—	7.9	bulk, *in situ*	interstitial fiberdetectors	Diffusion Theory	Preuss *et al.*, 1982
	630 789	— —	1.21 0.5	— —	11.8 5.4	— —	6.9 3.0	bulk	interstitial cylindrical source and flat cleave fiber detectors	Grosjean's model (spherical geometry)	Arnfield *et al.*, 1992
Human	630	—	—	—	—	—	4.0	bulk, *in situ*	interstitial fiber detectors	Diffusion Theory	Eichler *et al.*, 1977
Pig cortex	630	—	—	—	—	—	4.8	bulk, *in situ*	interstitial fiber detectors	Diffusion Theory	Doiron *et al.*, 1983
Liver											
Cow	633 1064 1320	— — —	3.21 0.53 0.70	— — —	5.23 1.76 1.2	— — —	6.8 3.2 2.0	frozen sections (slab), thawed, also bulk	integrating sphere; interstitial detectors for μ_{eff}	Diffusion Theory; Phase function fit	Karagiannes *et al.* 1989

Tissue	λ (nm)	μ_t cm^{-1}	μ_a cm^{-1}	μ_s cm^{-1}	μ_s(1-g)	g	μ_{eff} cm^{-1}	Tissue Preparation and geometry	Experimental method	Theory (Inverse form)	Reference
Liver											
Cow	355	—	29.4	—	31.5	—	73.3	bought, refrigerated, no saline or water rinse, slab	photoacoustic transducer to detect shape + peak amplitude of laser-induced pressure wave.	Acoustic Theory	Oraevsky/Jacques, 1993
	532	—	10.9	—	11.9	—	27.3				
	1064	—	0.1	—	12.0	—	1.9				
Human	630	—	3.2	414	—	0.95 [e]	—	*post mortem,* thin slab	integrating sphere absorb-ance; goniophotometry	Beer's Law	Andreola *et al,* 1988
	515	304	18.9	285	—	—	—	frozen sections, slab	——— as above ———	Beer's Law	Marchesini *et al.* 1989
Pig	630	—	2.7	—	17.0	—	12.6–13.0[(1)]	*post mortem, in situ*	interstitial fiberoptic detectors	Diffusion Theory	Wilson *et al.*, '86b, [(1)] Doiron *et al.*, '83
	630	—	2.3	—	9.5	—	—	bulk	interstitial cylindrical source and flat cleave fiber detectors	Grosjean's model (spherical geometry)	Arnfield *et al.*, 1992
	789	—	0.9	—	6.5	—	—				
	355	—	27.6	—	28.9	—	68.4	bought, refrigerated, no saline or water rinse, slab	photoacoustic transducer to detect shape + peak amplitude of laser-induced pressure wave.	Acoustic Theory	Oraevsky/Jacques1993
	532	—	7.9	—	11.7	—	23.4				
	1064	—	0.08	—	10.1	—	1.6				
Rabbit	632.8	—	11.3	190	8.9	0.934	21.9 (12.5 Wils)	resected <10 min. after rat sacrifice; all slabs (1<t<10) within 12 h.	two integrating spheres, direct T (include sphere corrections)	Inverse Adding-Doubling	Beek *et al.*, 1993
Rat	1064	—	1.29±.12	63.4±.8	8.25	0.870	—	bought, no rinse or refrigeration, slab	integrating sphere + baffle corrections; goniophoto-metry on 25μm samples	Inverse Monte Carlo [Piet, 1992]	Essenpreis, 1992
	1320	—	4.29±.14	15.8±1.3	2.44	0.846	—				
	2100	—	21.2±1.8	27±11	5.42	0.800[##]	—				
	355	—	37.1	—	20.5	—	80.1	fresh from sacrificed rat, refrigerated, used within 24 hrs.	photoacoustic transducer to detect shape + peak amplitude of laser-induced pressure wave.	Acoustic theory	Oraevsky/Jacques1993
	532	—	8.2	—	10.3	—	21.3				
	1064	—	0.14	—	11.3	—	2.2				
Rat	355	—	34	—	19	—	73	freshly excised from sacrificed rat	integrating sphere	Inverse Adding-Doubling	Jacques, 1993a
	400	—	47	—	18	—	96				
	450	—	36	—	16	—	74				
	500	—	12	—	13	—	29				
	550	—	23	—	11	—	49				
	600	—	9.6	—	8.9	—	23				
	633	—	3.0	—	7.5	—	9.8				
	650	—	2.7	—	7.6	—	9.0				
	700	—	1.5	—	6.8	—	6.2				
	750	—	1.3	—	6.5	—	5.6				
	810	—	0.72	—	5.6	—	3.7				
Rat	488	—	12.2	173.5	—	0.93	29.9	fresh and frozen sections thin slab between glass slides	total R and total R unscattered T	diffusion theory (Delta-Eddington)	Parsa et al, 1989
	633	—	6.5	143.7	—	0.95	16.3				
	800	—	5.7	97.0	—	0.94	14.0				
	1064	—	5.9	60.9	—	0.92	13.8				
	1320	—	6.6	44.2	—	0.91	14.5				
	2100	—	27.2	24.5	—	0.80	51.2				

[e] average value
[##] reference [165] in Matthias diss.

Tissue	λ (nm)	μ_t cm^{-1}	μ_a cm^{-1}	μ_s cm^{-1}	μ_s(1-g)	g	μ_{eff} cm^{-1}	Tissue Preparation and geometry	Experimental method	Theory (Inverse form)	Reference
Liver											
Rat	850	—	0.73	—	5.4	—	3.6	freshly excisedfrom sacrificed rat	integrating sphere	Inverse Adding-Doubling	Jacques, 1993a
	900	—	0.75	—	5.0	—	3.6				
	950	—	0.73	—	4.8	—	3.5				
	1000	—	0.61	—	4.5	—	3.1				
	1064	—	0.34	—	4.2	—	2.2				
	1100	—	0.29	—	4.1	—	2.0				
	632.8		3.8	280	13.0	0.952	13.8	excised<10 min. post rat sacrifice; all slabs (1<t<10) within 12 h.	two integrating spheres, direct T (incl. sphere corrections)	Inverse Adding-Doubling	van Hillergersberg *et al.*, 1993
	1064		2.4	196	11.2	0.948	9.8				
Lung											
Dog	632.8		3.2±.7	230±5	15.4±4.3	0.935±.017	11.6±1.5	—— as above ——	—— as above ——	—— as above ——	Beek *et al.*, 1993a
Human											
deflated lung	633	—	—	—	—	—	11.0	*post mortem, in situ*	interstitial fiber detectors	Diffusion Theory	Doiron *et al.*, 1982
Bronchial mucosa	633	—	—	—	—	—	9.1	*post mortem, in situ*	—— as above ——	— as above —	Doiron *et al.*, 1982
Squamous cell carcinoma	633	—	—	—	—	—	6.3	*post mortem, in situ*	—— as above ——	— as above —	Doiron *et al.*, 1983
Pig	632.8	—	2.0±.1	301±22	19.7±1.4	0.933±.003	11.3±.6	excised <10 min. post sacrifice; used within 12 h; slabs (1<t<10)	two integrating spheres, direct T (incl. sphere corrections)	Inverse Adding-Doubling	Beek *et al.*, 1993a
	790	—	2.4±.3	263±18	20.0±1.7	0.926±.004	12.4±1.3				
	850	—	0.76±.07	278±21	10.9±.7	0.957±.002	4.8±.3				
Rabbit	632.8	—	2.8±.2	330±21	30.8±3.2	0.904±.012	16.5±1.0	—— as above ——	—— as above ——	—— as above ——	Beek *et al.*, 1993a
Meniscus											
Human	360	—	13	—	108	—	69	frozen, thawed, slab	integrating sphere	Inverse Adding-Doubling	Schwartz *et al.*, 1993
	400	—	4.6	—	67	—	31				
	488	—	1	—	30	—	9.6				
	514	—	0.73	—	26	—	7.7				
	630	—	0.36	—	11	—	3.5				
	800	—	0.52	—	5.1	—	3.0				
	1064	—	0.34	—	2.6	—	1.7				
Muscle											
Chicken	633	230	0.12	—	8.0	—	1.7	bulk, coarsely ground	interstitial flat cut detectors;	Diffusion Theory	Wilson *et al.*, 1986a
		—	—	—	—	—	1.34	—— as above ——	—— as above ——		Marijnissen *et al.*, 1984
		345	—	—	—	0.965	—	ground, frozen, thinly sliced, thawed	direct T, goniophotometry	Beer's Law and Mie Theory	Flock *et al.*, 1987

Tissue	λ (nm)	μ_t cm^{-1}	μ_a cm^{-1}	μ_s cm^{-1}	$\mu_s(1-g)$	g	μ_{eff} cm^{-1}	Tissue Preparation and geometry	Experimental method	Theory (Inverse form)	Reference
Muscle											
Chicken	630 789	— —	0.12 0.06	— —	9.03 7.57	— —	— —	*in situ,* bulk	interstitial cylindrical source (2 mm) and flat cleave fiber detectors	Grosjean's model (spherical geometry)	Arnfield *et al.*, 1992
Cow	630	—	—	—	—	—	4.3-6.9	*post mortem,* bulk, *in situ*	interstitial flat cut detectors	Diffusion Theory	Doiron *et al.*, , 1983 Preuss *et al.*, 1982 Bolin *et al.*, 1987
	633	121	1.50	—	7.0	—	6.2	*in situ*, bulk	interstitial fiberoptic detectors	Diffusion Theory + "Added Absorber"	Wilson *et al.*, 1986a
	633	328	—	—	—	0.941	—	ground, frozen, thinly sliced, thawed	direct T; goniophotometry	Beer's Law and Mie Theory	Flock *et al.*, 1987
	633 1064 1320	— — —	1.7 1.2 2.3	— — —	4.4 2.8 2.4	— — —	3.9 2.3 5.6	Frozen sections, thawed, slab	integrating sphere: R and T	Similarity transform, numerical fit to 2-parm phase function	Karagiannes *et al.*, 1989
Human	515	541	11.2	530	—	—	—	frozen sections, thin slab	absorbance with IS, direct T from goniophotometry	Beer's Law	Marchesini *et al.*, 1989
Pig	633	41.0	1.0	40.0	1.2	0.97	—	frozen, thawed, slab	integrating sphere	Monte Carlo	Wilksch *et al*., 1984
	1060	—	2.0	—	—	—	—	bulk slab	photoacoustic transducer	Acoustic Theory	MacLeod *et al*., '88
	630 633	— —	1.2 0.59	239 179	62.1 24.7	0.732 0.858	15.0 6.7	excised <10 min. post sacrifice; used within 12 h; slabs (1<t<10)	two integrating spheres, direct T (incl. sphere corrections)	Inverse Adding-Doubling	Beek *et al.*, 1993a
Rabbit	514.5 630	— —	— —	— —	— —	— —	2.0-10.0 1.1-12.5	*post mortem, in situ*	interstitial fiber detectors	Diffusion Theory	Doiron *et al.*,, 1983 Wilson *et al.*, 1985
	630 632.8	— —	1.4 0.74	110 140	16.5 4.4	0.846 0.968	8.4 15.0	excised <10 min. post sacrifice; used within 12 h; slabs (1<t<10)	two integrating spheres, direct T (incl. sphere corrections)	Inverse Adding-Doubling	Beek *et al.*, 1993a
Myocardium											
Dog	514	—	10.1	—	8.1	—	23.4	*post mortem,* moist, slab	two integrating spheres (excl. sphere corrections)	Diffusion Theory (∂-Eddington)	Cheong, 1990
	1320	—	2.3	—	3.5	—	6.3	—— as above ———	—— as above ———	—– as above —	
	1064 (1) (2)	—	0.6 0.4	—	4.8 4.5	—	3.1 2.4	—— as above ———	(1) —— as above ——— (2) integrating sphere, direct T	(1) —– as above —– (2) Diffusion + KM	1 Cheong, 1990 2 Splinter *et al.*, 1991

Tissue	λ (nm)	μ_t cm^{-1}	μ_a cm^{-1}	μ_s cm^{-1}	$\mu_s(1-g)$	g	μ_{eff} cm^{-1}	Tissue Preparation and geometry	Experimental method	Theory (Inverse form)	Reference
Myocardium											
Dog	630	—	2.0	159	23.0	0.854	12.1	excised <10 min. post sacrifice; used within 12 h; slabs (1<t<10)	two integrating spheres, direct T (incl. sphere corrections)	Inverse Adding-Doubling	Pickering *et al.*, 1992a, Beek *et al.*, 1993a
	632.8	—	2.0-2.1	160-191	11.2-11.3	0.93-0.944	8.9-9.1				
	790	—	0.98	164	6.0	0.943	3.4				
Human											
normal	1064	—	0.3	178	—	0.964	—	post mortem, kept in 3-5°C saline prior to use, slab	integrating sphere, direct T	Diffusion and 3-flux KM Theories	Splinter *et al.*, 1989b, 1991
scarred	1064	—	0.4	13.7	—	0.975	—				
epicardium	1064	—	0.35	167	—	0.983	—				
endocardium	1064	—	0.07	136	—	0.973	—				
Pig	1064	—	0.44±.05	—	4.3±.3	0.0[1]	—	Fresh, kept on ice 30-60 min., 2-5mm slabs	2 integrating spheres: R and T	Exact transport solution for isotropic case [Reichmann]	Derbyshire *et al.*, 1990
Prostate											
Canine	355	—	9.2	—	47.1	—	39.4	resected, refridgerat-ed, used within 24 h, slab	photoacoustic transducer to detect shape + peak amplitude of laser-induced pressure wave.	Acoustic Theory	Oraevsky/Jacques1993
	532	—	2.4	—	23.8	—	13.7				
	1064	—	0.04	—	13.0	—	1.25				
Human	633	9.6	0.7±2	—	8.6±.5	0.0[1]	4.3±.5	*post mortem*, used within 24-48 h, *in situ*, whole organ	interstitial source and detectors, direct T	Diffusion Theory, Beer's Law	Pantelides *et al.*, 1990
	612	—	—	—	—	—	6.3				
	594	—	—	—	—	—	9.1				
	543	—	—	—	—	—	18.2				
	1064	—	1.47±.24	47±13	6.43	0.862	—	*post-mortem*, native, slab	integrating sphere + baffle corrections; goniophoto-metry	Inverse Monte Carlo [Piet, 1992]	Essenpreis, 1992
Skin											
Human											
Stratum corneum	193	—	6000	—	—	—	—	frozen, thawed, slab	direct T	Beer's Law	Watanabe *et al.*, '88
Dermis	630-635	243-246	1.8-1.9	—	—	—	—	frozen flaps, thawed	integrating sphere (μ_a); goniometer: direct T	Beer's Law	Andreola *et al.*,'88 Marchesini *et al.*,'89
	633	190	2.7	187	35.5	0.81	—	fresh + frozen, 85% hydration, slab	integrating sphere + gonio-photometry	Diffusion Theory; HG fit	Jacques *et al.*, 1987b
Pig epidermis	632.8	—	1.0±0.1	492±17	22.7±0.8	0.953±.001	8.3±0.4	excised <10 min. post sacrifice; used within 12 h; slabs (1<t<10)	integrating sphere, direct T (include sphere corrections)	Inverse Adding-Doubling	Beek *et al.*, 1993a
	790	—	2.4±0.2	409±14	19.3±0.6	0.952±.001	12.3±0.6				
	850	—	1.6±0.1	403±20	14.3±1.5	0.962±.005	8.5±0.6				

[1] Scattering isotropy assumed

Tissue	λ (nm)	μ_t cm^{-1}	μ_a cm^{-1}	μ_s cm^{-1}	$\mu_s(1-g)$	g	μ_{eff} cm^{-1}	Tissue Preparation and geometry	Experimental method	Theory (Inverse form)	Reference
Skin											
Pig dermis	632.8	—	0.89±0.1	289±7	21.1±0.4	0.926±.002	7.1±0.5	excised <10 min. post sacrifice; used within 12 h; slabs (1<t<10)	integrating sphere, direct T (include sphere corrections)	Inverse Adding-Doubling	Beek *et al.*, 1993a
	790	—	1.8±0.2	254±5	13.9±0.3	0.945±.001	8.8±0.6				
	850	—	0.33±.03	285±5	9.0±0.2	0.968±.001	3.0±0.1				
Rabbit	630	—	0.94±.13	213±21	40.0±2.2	0.812±.017	10.7±1.4	—— as above ——	——— as above ———	—— as above ——	Beek *et al.*, 1993a
	632.8	—	0.33±.02	306±12	31.6±2.2	0.898±.007	5.4±0.2				
	790	—	0.70±.07	321±8	18.4±0.5	0.940±.003	5.9±0.4				
Rat	355	—	7.3	—	120	—	53	freshly excised, slab	integrating sphere	Inverse Adding-Doubling	Jacques, 1993a
	400	—	3.2	—	116	—	34				
	450	—	1.3	—	67	—	16				
	500	—	0.48	—	45	—	8.1				
	550	—	0.47	—	33	—	6.9				
	600	—	0.26	—	25	—	4.5				
	633	—	0.22	—	23	—	3.9				
	650	—	0.22	—	21	—	3.7				
	700	—	0.22	—	19	—	3.5				
	750	—	0.25	—	17	—	3.6				
	810	—	0.15	—	13	—	2.4				
	850	—	0.19	—	12	—	2.7				
	900	—	0.16	—	11	—	2.4				
	950	—	0.29	—	11	—	3.1				
	1000	—	0.39	—	9.8	—	3.4				
	1064	—	0.23	—	9.1	—	2.5				
Tumors											
Brain, intra-cranial (Human)[f]	488	—	—	—	—	—	7.1-20.0	freshly resected, *in situ*, 5-10 cm^3 bulk	interstitial fiber detectors	Diffusion Theory	Svaasand *et al.*, 1985
	514	—	—	—	—	—	7.1-20.0				
	635	—	—	—	—	—	5.9-3.9				
	1060	—	—	—	—	—	3.3-1.9				
Brain (Human)	630	—	—	—	—	—	3.8-8.3	30-60 min. post-resection, *in situ*	interstitial fiber detectors	Diffusion Theory (spherical geometry)	Svaasand *et al.*, 1985
Prostate (rat) R3327-AT	633	271	0.49	270.	8.1-5.4	.97-.98	3.6-2.9	excised, frozen, cut into ~120 µm slabs,	integrating sphere (μ_a)	Diffusion Theory	Arnfield *et al.*, 1988
Sarcoma (rat)	630	—	—	—	—	—	2.3	*post mortem*, *in situ*, bulk	interstitial fiber detectors pointed in x, y, & z directions	Diffusion Theory	Doiron *et al.*, 1982
	514.5	—	—	—	—	—	4.8				
Fibrosarcoma (rat)	630	—	—	—	—	—	4..4-9.8	bulk	interstitial fiber detectors	Beer's Law	Driver *et al.*, 1988
Uterus											
Human	635	394	0.35	394	—	0.69	—	frozen sections, slab	integrating sphere (μ_a), goniophotometry (μ_t)	Beer's Law	Marchesini *et al.*, 1989

[f] intracranial tumors: meningiomas, astrocytomas, glioblastomas

SUMMARY OF OPTICAL PROPERTIES OF TISSUE *IN VIVO*

Tissue	λ (nm)	μ_t cm^{-1}	μ_a cm^{-1}	μ_s cm^{-1}	$\mu_s(1-g)$	g	μ_{eff} cm^{-1}	Tissue Preparation and geometry	Experimental method	Theory (Inverse form)	Reference
Brain											
Cat	405-410 545 577 631	— — — —	— — — —	— — — —	— — — —	— — — —	44.1 34.4 25.9 5.0-9.8	*in situ*, intact organ	interstitial fiberoptic detectors	Diffusion Theory	Doiron *et al.*, '82,'83
Human	630	—	—	—	—	—	4.8-10.0	*in situ*	interstitial detectors during PDT with embedded inflated balloon light source	Diffusion Theory (spherical solution)	Muller *et al.*, 1986
Pig	630	—	—	—	—	—	3.7-4.5	*in situ*	interstitial detectors with surface irradiation (source)	Diffusion Theory	Wilson *et al.*, 1985
Brain tumors	630	—	—	—	—	—	2.2-6.6	*in situ*	interstitial detectors with interstitial spherical source, post-PDT measurements	Diffusion Theory	Wilson *et al.*, 1986c; Muller *et al.*, 1986
Liver											
Pig (inspiration) (expiration)	632.8	— —	— —	— —	— —	— —	2.5 3.0	resected whole organ, *in situ*	interstitial isotropic detectors	Diffusion Theory	Beek *et al.*, 1993b
Rabbit	630	—	—	—	—	—	9.0-25.0	*in situ*	interstitial detectors with surface irradiation (source)	Diffusion Theory	Wilson *et al.*, 1985
Muscle											
Rabbit	630 514	— —	— —	— —	— —	— —	1.6-4.8 4.5-7.7	*in situ*, intact, ~30-40 mm^3 bulk	interstitial fiberoptic detectors	Diffusion Theory	Wilson *et al.*, 1985 Doiron *et al.*, '82,'83
Tumors											
Human retino-blastoma (athymic mice)	488/514 630 668 1064	— — — —	— — — —	— — — —	— — — —	— — — —	6.25 3.03 2.8 1.3	*in situ*, intact	interstitial spherical tip fiberoptic detectors	Diffusion Theory (spherical solution)	Svaasand *et al.*, 1989
Mammary car-cinoma (C3H /HEJ mice)	488/514 630 668 1064	— — — —	— — — —	— — — —	— — — —	— — — —	9.1 5.0 4.3 2.7	*in situ*, intact	——— as above ———	——— as above ———	—— as above ——
B16 melanotic melanoma (C57/B16 mice)	630 668 1064	— — —	— — —	— — —	— — —	— — —	20.0 20.0 5.0	*in situ*, intact	——— as above ———	——— as above ———	—— as above ——

Tissue	λ (nm)	μ_t cm^{-1}	μ_a cm^{-1}	μ_s cm^{-1}	$\mu_s(1-g)$	g	μ_{eff} cm^{-1}	Tissue Preparation and geometry	Experimental method	Theory (Inverse form)	Reference
Tumors											
Prostate (rat)											
• R3327-At	630	—	0.97	—	13.2	—	—	*in situ*	interstitial cylindrical diffuser source and flat fiber detectors	Grosjean's model (spherical geometry)	Arnfield *et al.*, 1992
	789	—	0.6	—	6.2	—	—				
• R3327-H	630	—	1.53	—	11.4	—	—	*in situ*	——— as above ———	——— as above ———	—— as above ——
	789	—	0.96	—	7.86	—	—				
Breast (human)	630	—	0.31	—	9.41	—	2.14-3.4	*in situ*	interstitial cylindrical probes (2 mm long) for source and detectors; correct for back-scatter at probe interface	Diffusion Theory	Driver *et al.*,1991

SUMMARY OF OPTICAL PROPERTIES OF THERMALLY COAGULATED TISSUES *IN VITRO*

Tissue / Condition	λ (nm)	μ_t cm^{-1}	μ_a cm^{-1}	μ_s cm^{-1}	μ_s(1-g)	g	μ_{eff}	Tissue / sample preparation	Heating method	Measurement method	Theory (Inverse form)	Reference
Aorta												
Human:												
• Normal native	308	—	33	—	77	—	104	freshly resected, slab	foil-wrapped specimens inside 85°C water bath	integrating sphere; 308 nm selected from spectra collected with optical multichannel analyzer	Adding-doubling	Oraevsky *et al.*, 1992
coagulated 85°C		—	44	—	270	—	204					
• Fibrous plaque native	308	—	24	—	81	—	87					
coagulated 85°C		—	34	—	272	—	177					
Human												
native	1064	—	0.53±.09	239±45	23.9	0.900[a]		*post mortem*, slab	immersed in 70°C water bath for 10 min, tissue sealed in aethylene bag	integrating sphere, goniophotometry for g using 25 µm specimens	Monte Carlo [Piet, 1992]	Essenpreis, 1992
coagulated		—	0.46±.18	293±73	29.3	0.900						
Liver												
Rat												
native	1064	—	1.3±.1	63±7	8.25	0.870		freshly excised, slab	immersed in 70°C water bath for 10 min, tissue sealed in aethylene bag	integrating sphere, goniophotometry for g using 25 µm specimens	Monte Carlo [Piet, 1992]	Essenpreis, 1992
coagulated		—	0.8±.1	141±11	16.2	0.885						
frozen		—	1.9±.2	20±5	1.68	0.915						
native	1320	—	4.3±.2	16±1	2.44	0.846						
coagulated		—	3.6±.1	88±9	22.8	0.866		—— as above ——	—— as above ——	—— as above ——	—— as above ——	– as above –
frozen		—	2.9±.2	6±2	0.60	n/a						
native	2100	—	21.2±2	27±11	0.542	0.800[a]						
coagulated		—	22.0±2	43±5	0.855	0.800		—— as above ——	—— as above ——	—— as above ——	—— as above ——	– as above –
Frozen		—	21.5±.9	13±4	0.254	0.800						
Wag/Rij rats												
native	1064	—	13±4	204±47	16.3	0.92±.05	—	Freshly excised, sectioned into 250-540 µm slabs, mounted between special heater slides	samples diffusively heated by electrical-ly resistive slides under three different voltages and heating rates for 960-980 s	two integrating spheres; direct T measurement (incl. sphere corrections)	Adding-Doubling Theory	Pickering *et al.*, 1992c
coagulated at 3 heating rates:												
• 15V(600s)/20V (360s)/25V		—	13	184	—	0.917						
• 25V(contd.)		—	11	175	—	0.912						
• 30V(contd.) after 960-980 s		—	10.8	161	—	0.893						

[a] g-value assumed

Tissue / Condition	λ (nm)	μ_t cm^{-1}	μ_a cm^{-1}	μ_s cm^{-1}	μ_s(1-g)	g	μ_{ef} cm^{-1}	Tissue / sample preparation	Heating method	Measurement method	Theory (Inverse form)	Reference
Myocardium												
Dog												
native	1064	——	0.43±.2	173±2	——	0.974±.008	——	excised, kept at 3-5°C, embedded in highly concentrated gelatin, chilled at 33 °C, cut into 600 µm slabs.	irradiated with 1 cm diameter Nd: YAG beam at 50W, 20-40s	two integrating spheres; direct T measured at 70 cm from sample	3-flux modified Kubelka-Munk (equivalent to Diffusion Model)	Splinter *et al.*, 1991
coagulated	1064	——	0.35±.2	246±2	——	0.96±.02	——					
native (≤ 45°C)	632.8	——	2.0±.4	11.2	160±30	0.93±.02	——	freshly excised, ≤75 µm slices held between glass slides.	foil-wrapped slabs slow-heated for 1000s in water bath raised to 37-75°C	two integrating spheres; direct T (incl. sphere corrections)	Adding-doubling	Pickering *et al.*, 1992a
coagulated at 45 —> 75°C		——	4.2±.2	——	——	0.71±.02	——					
Pig												
native	850	5	——	——	——	——	——	refrigerated 24 h; sliced into ~ 750 µm slabs held between glass slides.	immersed in water bath at 100 °C; T_c and temperature simultaneously monitored.	Infrared LED source with 850 nm peak; single detector recorded T_c	Bouguer's (Beer's) Law	Derbyshire *et al.*, 1990
coagulated		8	——	——	——	——	——					
native	1064	——	0.44±.05	——	4.3 ±.3	——	——	freshly excised, kept on ice for 30-60 min, cut into 2-5 mm slices	whole hearts micro-waved at 450W, 5-10 min, cooled for 30 min. and sliced	two integrating spheres with low level Nd:YAG irradiation delivered thro' fiber, beam divergence unknown	Reichman and Egan's model [*]; isotropy and n=1.33 assumed;	Derbyshire *et al.* 1990
coagulated		——	0.51±.09	——	1.7±1	——	——					
Prostate												
Human												
native	1064	—	1.5±.2	47±13	0.64	0.862	—	freshly excised, slab	immersed in 70°C water bath for 10 min, tissue sealed in aethylene bag	integrating sphere, goniophotometry for g using 25 µm specimens	Monte Carlo [Piet, 1992]	Essenpreis, 1992
coagulated		—	0.8±.2	80±12	1.12	0.861	—					

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