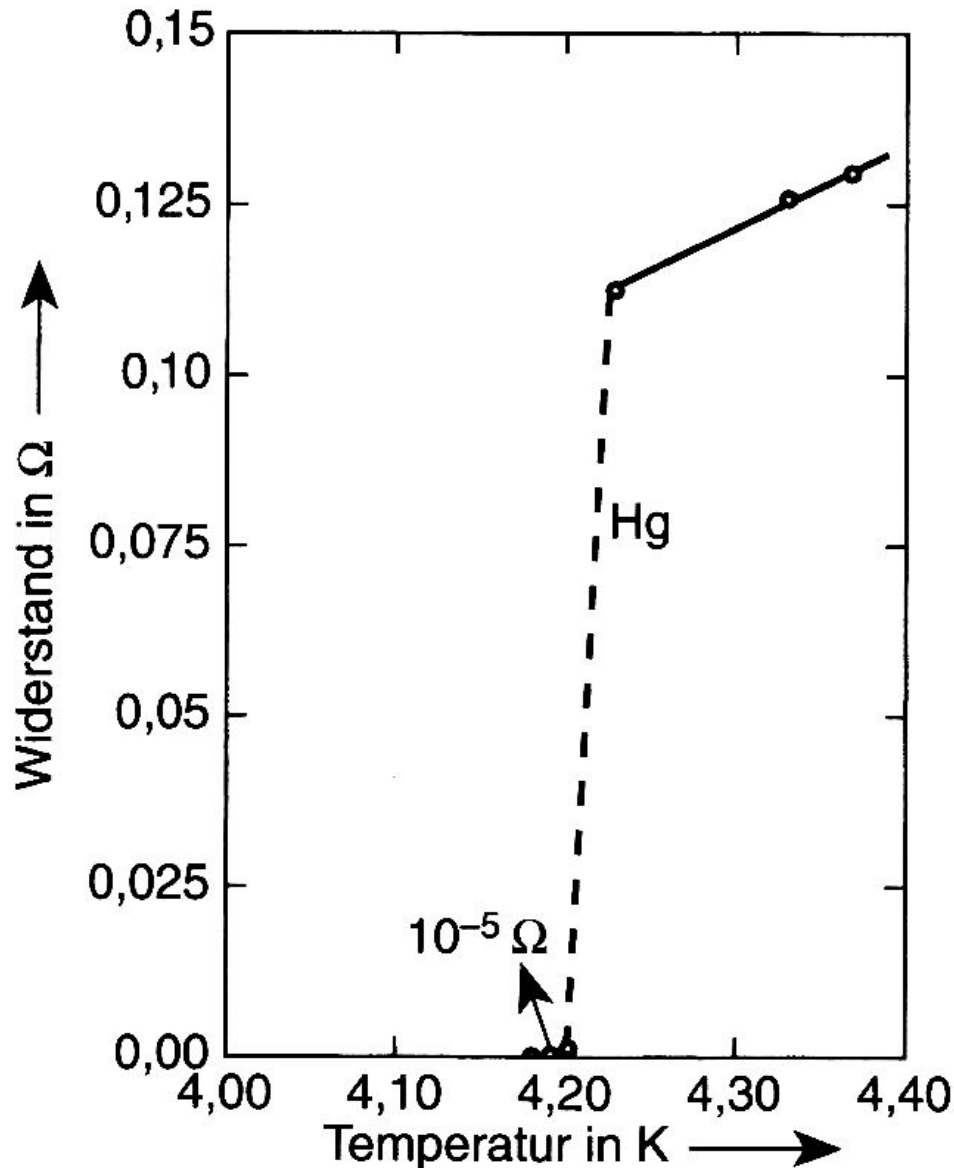


Superconductivity

Normal metal (N):

$$\rho = \rho_0 + a T^5 \quad \text{at } T \ll \theta_D$$

non-magnetic impurities & phonons



Superconductor:

$$\rho = 0 \quad \text{at } T < T_c$$



Heike Kamerlingh Onnes

naheliegende Anwendungen

verlustfreier Energietransport

Magnetfelderzeugung (NMR, Transrapid)

weniger naheliegend

Quantenbauelemente (SQUID superconducting quantum interference device, RSFQ rapid single flux quantum)

KNOWN SUPERCONDUCTIVE ELEMENTS

■ BLUE = AT AMBIENT PRESSURE
■ GREEN = ONLY UNDER HIGH PRESSURE

	IA												0					
1	1											2	2					
												III A	IV A	V A	VI A	VII A		
1	H											5	6	7	8	9	10	
2	3	4											13	14	15	16	17	18
	Li	Be											Al	Si	P	S	Cl	Ar
3	11	12	III B	IV B	V B	VI B	VII B	VII		IB	II B							
4	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	55	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
	Cs	Ba	*La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	87	88	89	104	105	106	107	108	109	110	111	112						
	Fr	Ra	+Ac	Rf	Ha	106	107	108	109	110	111	112						

SUPERCONDUCTORS.ORG

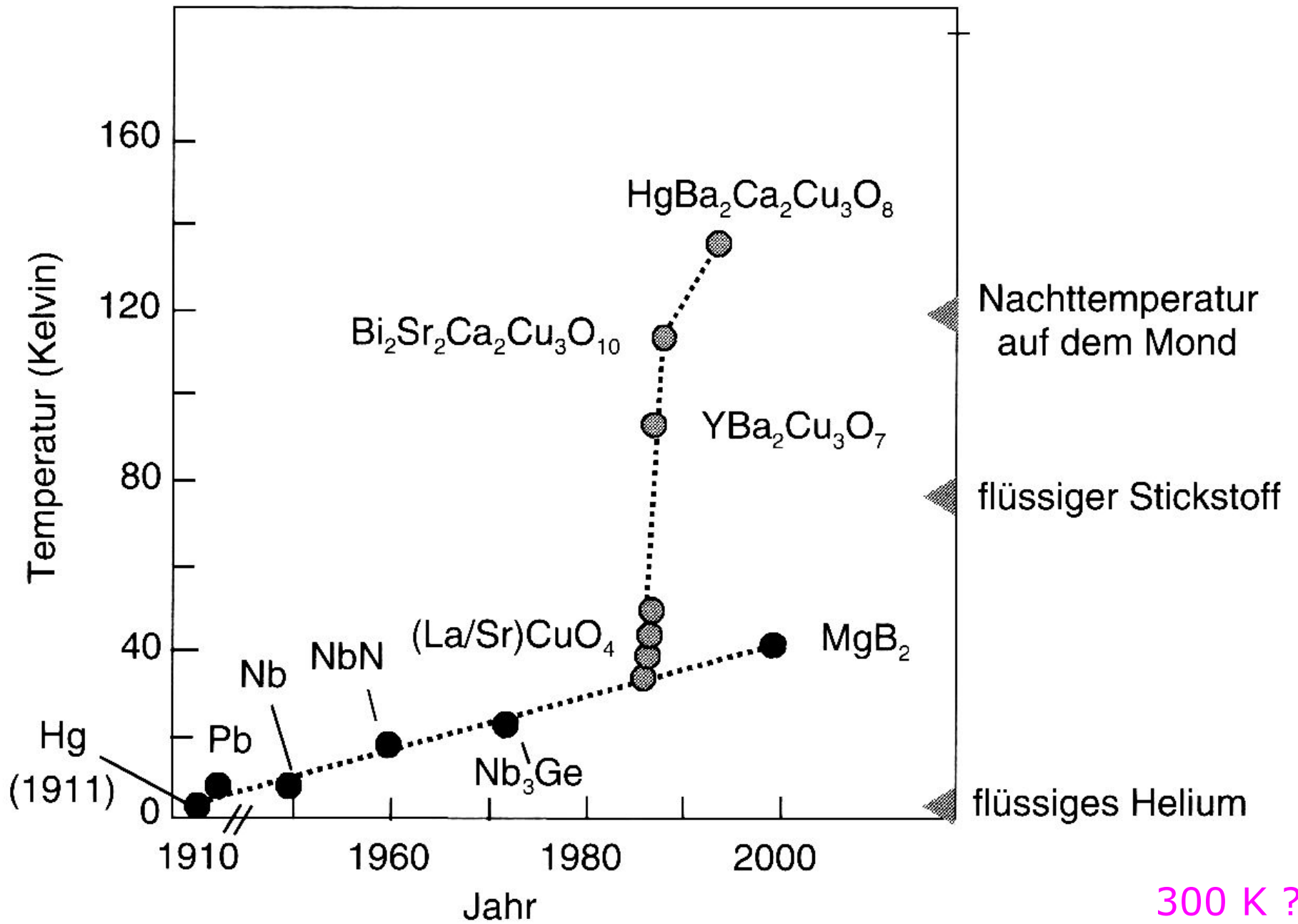
* Lanthanide Series	58	59	60	61	62	63	64	65	66	67	68	69	70	71
	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
+ Actinide Series	90	91	92	93	94	95	96	97	98	99	100	101	102	103
	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

Most metals are superconductors

Some Type 1 Superconductors

Lead (Pb)	7.196 K
Lanthanum (La)	4.88 K
Tantalum (Ta)	4.47 K
Mercury (Hg)	4.15 K
Tin (Sn)	3.72 K
Indium (In)	3.41 K
Thallium (Tl)	2.38 K
Aluminum (Al)	1.175 K
Gallium (Ga)	1.083 K
Molybdenum (Mo)	0.915 K
Zinc (Zn)	0.85 K
Osmium (Os)	0.66 K
Cadmium (Cd)	0.517 K
Ruthenium (Ru)	0.49 K
Titanium (Ti)	0.40 K
Uranium (U)	0.20 K
Hafnium (Hf)	0.128 K
Iridium (Ir)	0.1125 K
Beryllium (Be)	0.023 K
Tungsten (W)	0.0154 K
Lithium (Li)	0.0004 K
Rhodium (Rh)	0.000325 K

$T_c(t)$



300 K ?

Persistent current

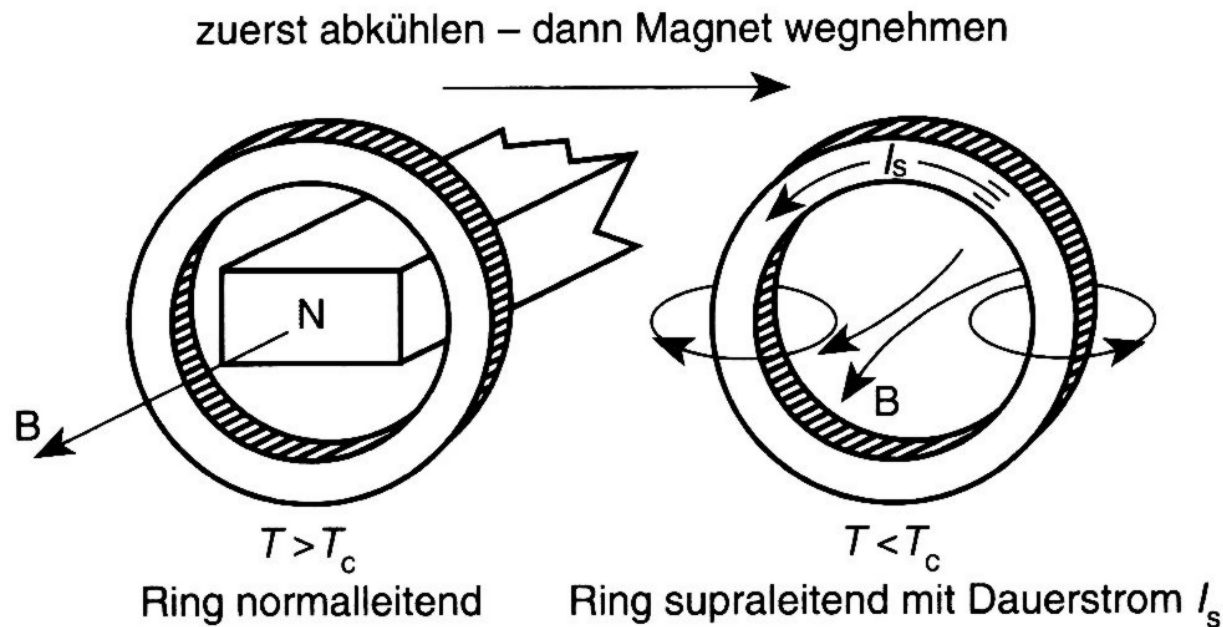
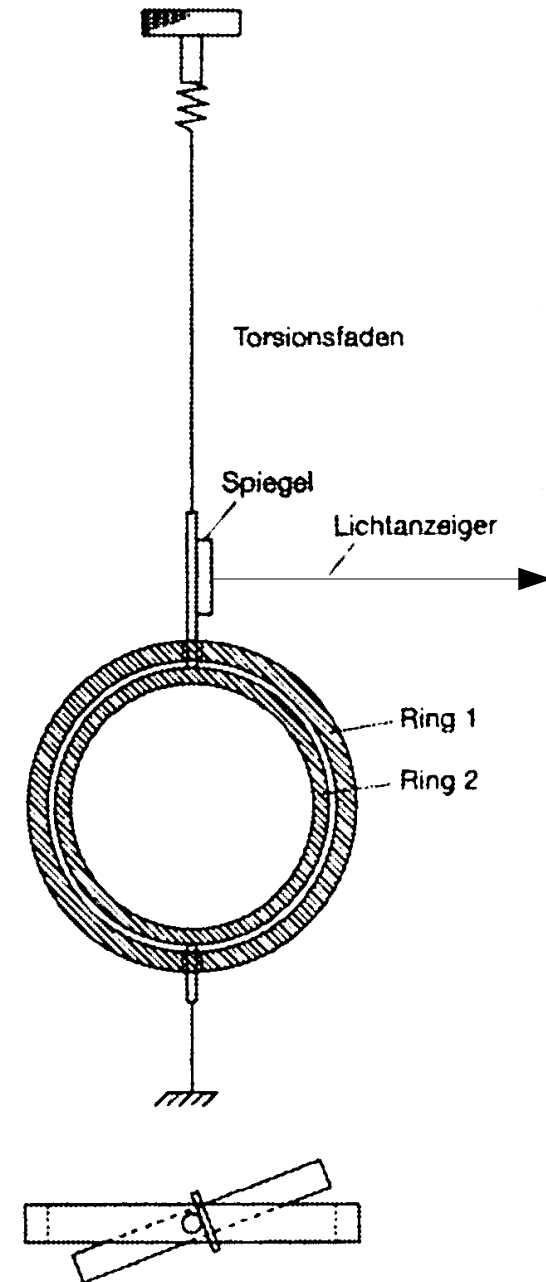


Abb. 1.1 Erzeugung eines Dauerstroms

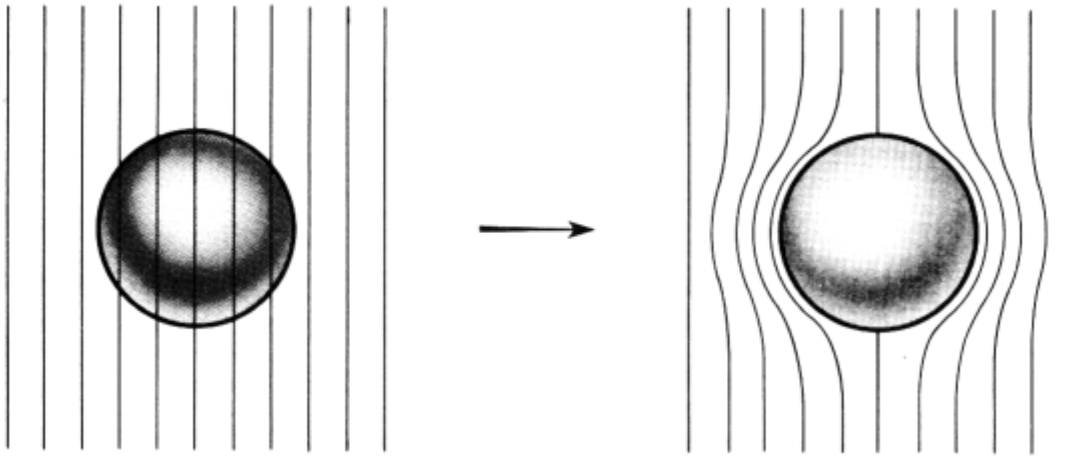
No decay detected over 2.5 years

No dissipation

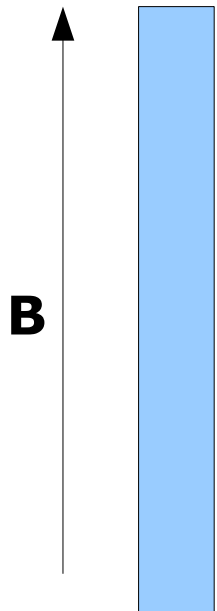
Minimum estimated decay time > age of universe



Meißner-Ochsenfeld-Effect (1933)



B field does not penetrate
= superconductors display
perfect diamagnetism



$$\mathbf{B}_{\text{in}} = 0$$

$$\rightarrow \mu_0 \mathbf{M} + \mathbf{B} = 0$$

$$\rightarrow \mathbf{M} = -\mathbf{B} / \mu_0$$

$$\rightarrow \chi = -1$$

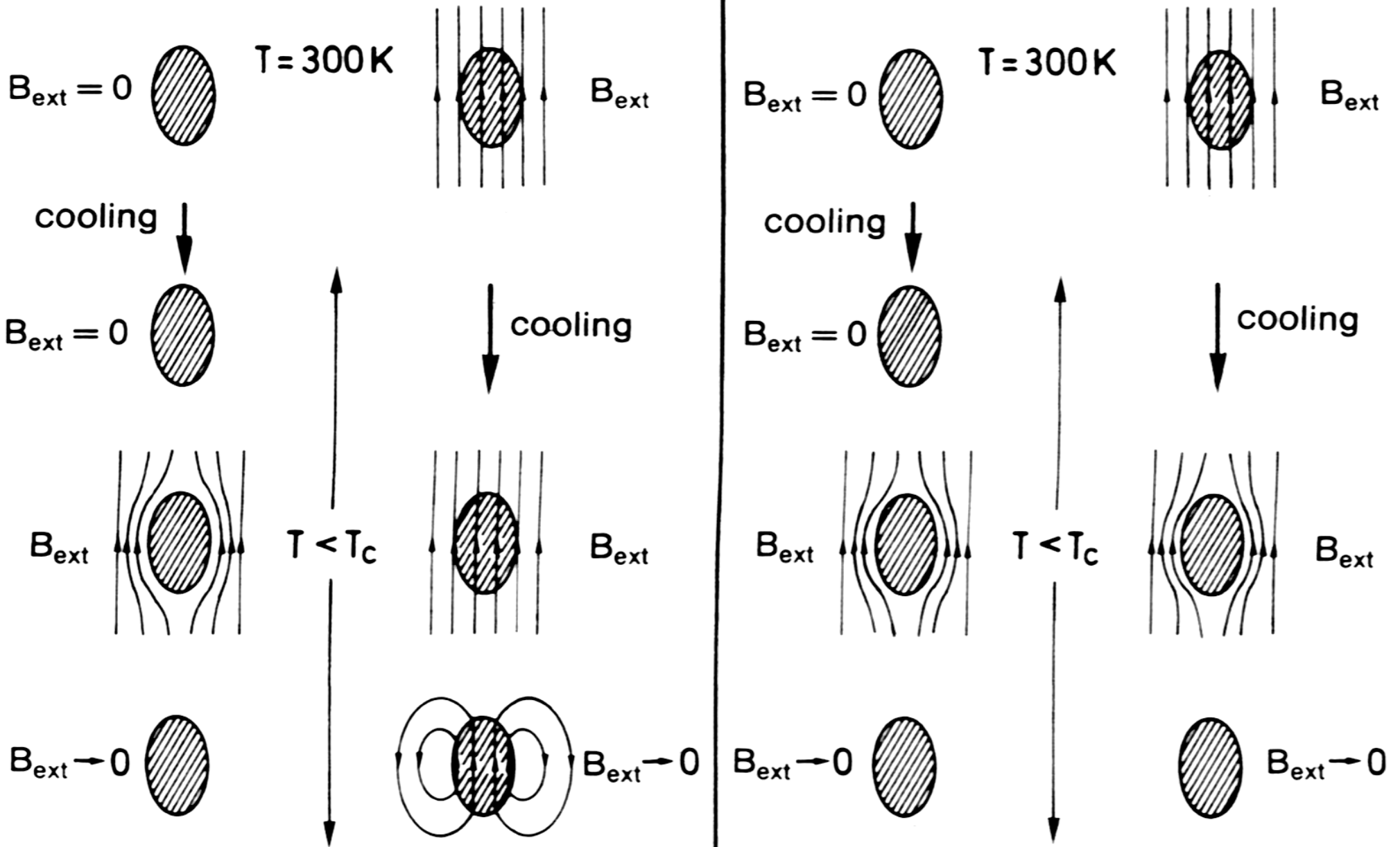


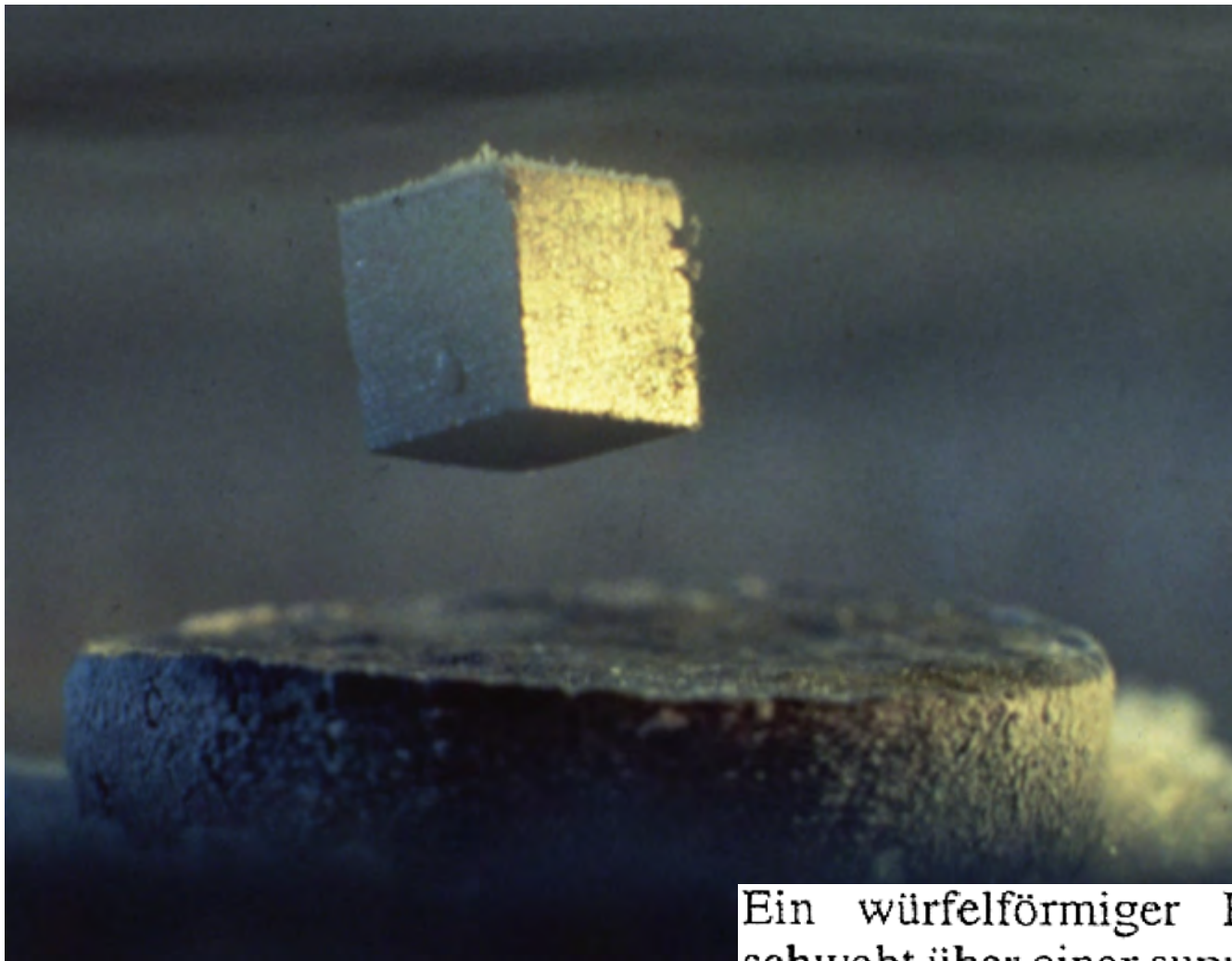
Walter Meißner

Perfekter Leiter vs. Supraleiter

Ideal conductor
($R = 0$)

Superconductor





Ein würfelförmiger Permanentmagnet schwebt über einer supraleitenden Scheibe aus dem Hochtemperatur-Supraleiter $\text{YBa}_2\text{Cu}_3\text{O}_7$. Das Schweben ist eine Folge des Meißner-Ochsenfeld-Effekts: Ein Supraleiter verhält sich wie ein idealer Diamagnet und stößt den Permanentmagneten ab. (© 1988 Richard Megna, Fundamental Photographs)