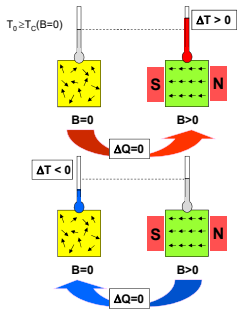
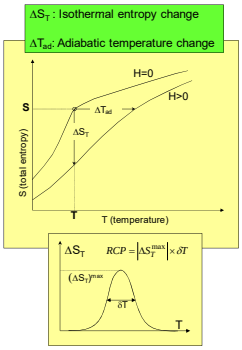
Magnetocaloric effect and magnetic refrigeration

F. Guillou, Y. Bréard, R. Daou, F. Veillon, V. Hardy, Laboratoire CRISMAT, Caen
U. Legait, A. Kedous-Lebouc, G2Elab, Saint-Martin d'Hères
P. Courtois, Institut Laue Langevin, Grenoble
L. Porcar, P. Plaindoux, D. Bourgault, Institut Néel, Grenoble

Magnetocaloric effect (MCE)

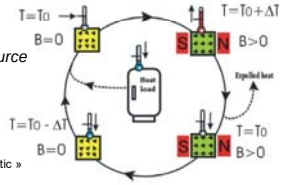
Example for a ferromagnet at $T_0 \geq T_C(B=0)$



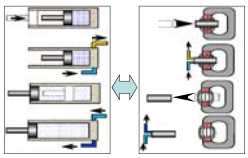


Magnetic Refrigeration (MR)

Pump heat from the Cold source and expell it to the Hot sink



« Conventional » « Magnetic »



Advantages:

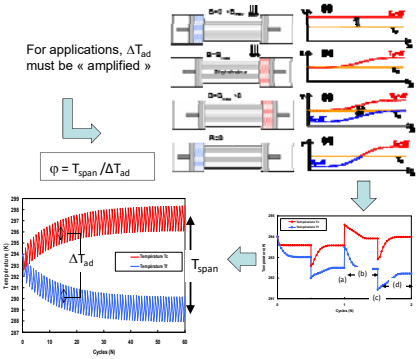
No harmful gas (ODP or GWP)

Better Coefficient Of Performance

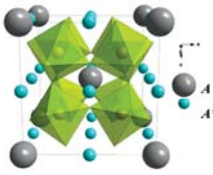
Active Magnetic Refrigeration (AMR)

For applications, ΔT_{ad} must be « amplified »

$\varphi = T_{span} / \Delta T_{ad}$



Studies of magnetocaloric oxides

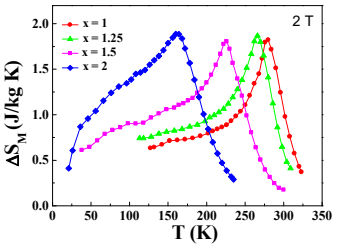


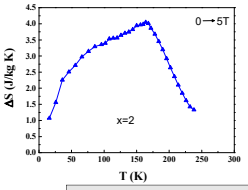
$(Ca^{2+})_A(Cu^{2+}_{3-x}Mn^{3+}_x)_{A'}(Mn^{4+}_{4-x}Mn^{3+}_x)_B O_{12}$

$CaCu_3Mn_4O_{12}$: Ferrimagnet T_C=355 K

Goal : as x ↑, one expects:
$J_{A'B}$ ↓ ⇒ T_c → 300K
M_{sat} ↑ ⇒ ΔS ↑
δT ↑ ⇒ RCP ↑

A' B
Mn^{3+} Cu^{2+} Mn





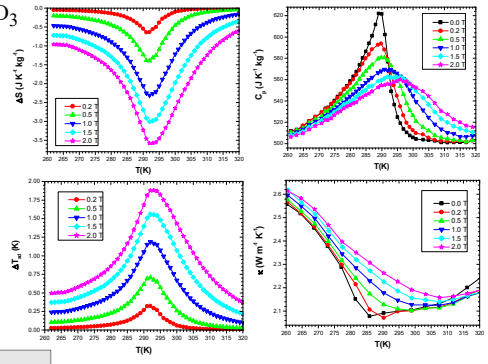
RCP~750 J/kg

> Gd_5SiGe_3
> $GdAl_2$

$(Pr^{3+}_{1-x}Sr^{2+}_x)_A(Mn^{3+}_{1-x}Mn^{4+}_x)_B O_3$

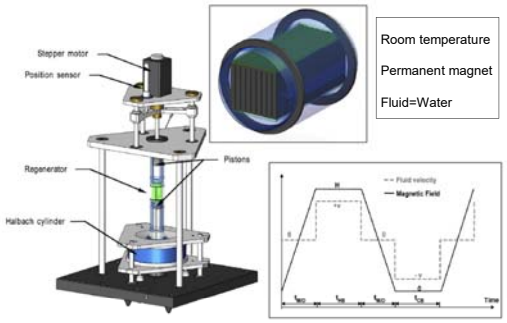
Goals :
-test directly the potentiality of oxides in magnetic refrigeration
-investigate experimentally various configurations of regenerators
-characterize all physical properties involved in AMR with resolutions vs. T and B high enough for numerical simulations

X=0.35



Direct tests of MR in oxides

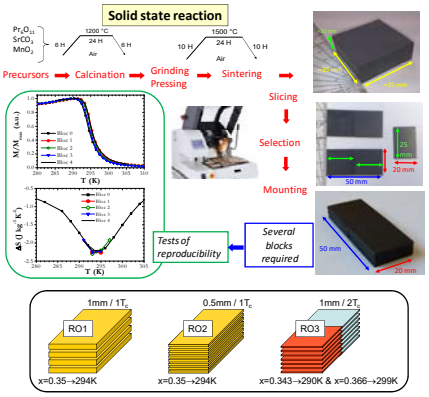
AMR test device of G2Elab



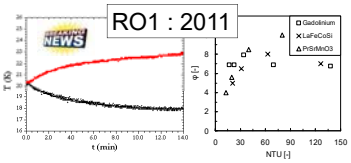
Room temperature
Permanent magnet
Fluid=Water

ANR MagCool

Preparation of $(Pr_{1-x}Sr_x)MnO_3$ regenerators



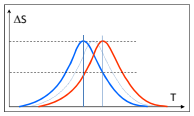
Results



$\varphi = T_{span} / \Delta T_{ad}$

$\frac{\partial T_f}{\partial x} = \pm NTU\,(T_s - T_f)$

Compound	Thickness(mm)	ΔT_{ad} (K)	$T_{span\ max}$ (K)	φ
Gd	1	1.45	11.5	7.9
$La(Fe,Co)_{13}Si$	1	1.0	8.0	8.0
(Pr,Sr)MnO3 RO1	1	0.5	4.6	9.2
(Pr,Sr)MnO3 RO2	0.5	0.5	8.2	16.4
(Pr,Sr)MnO3 RO3	1	0.5	4.2	8.4



$Biot = \frac{h \times e}{\kappa}$ ↓

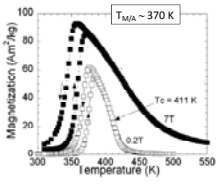
Characterizations of MCE in Heusler alloys

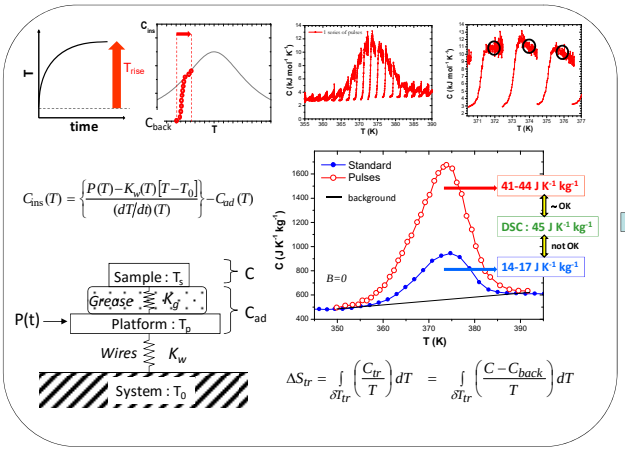
(Broad transition with Latent heat and Hysteresis) → New measuring technique for C(T)

$Ni_{45}Co_5Mn_{37.5}In_{12.5}$ single crystal

Martensite (enonmagnetic) | Austenite (Ferro) | Austenite (Para)

T_{M-A} T_C

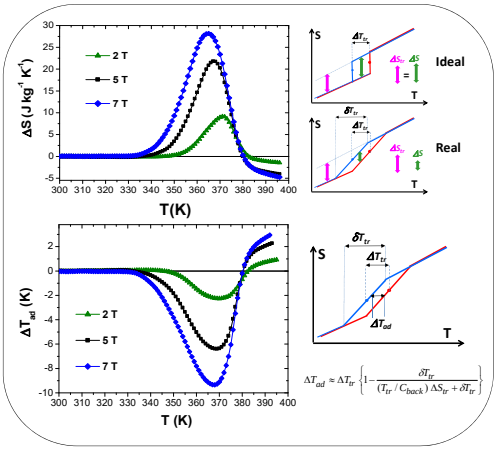




$C_{ins}(T) = \left\{\frac{P(T) - K_w(T)[T - T_0]}{(dT/dt)(T)}\right\} - C_{ad}(T)$

$\Delta S_{tr} = \int_{\delta T_{tr}} \left(\frac{C_{tr}}{T}\right) dT = \int_{\delta T_{tr}} \left(\frac{C - C_{back}}{T}\right) dT$

Impact of the transition width on MCE



$\Delta T_{ad} \approx \Delta T_{tr}\left\{1 - \frac{\delta T_{tr}}{(T_{tr}/C_{back})\,\Delta S_{tr} + \delta T_{tr}}\right\}$

ANR
Europe s'engage en Basse-Normandie
Région Basse-Normandie
CNRS
ENSICAEN
UNICAEN
Normandie Université
IRMA